DISCOVERY

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M.A., Ph.D., F.Inst.P.

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D.Sc., D.Eng., M.I.E.E.

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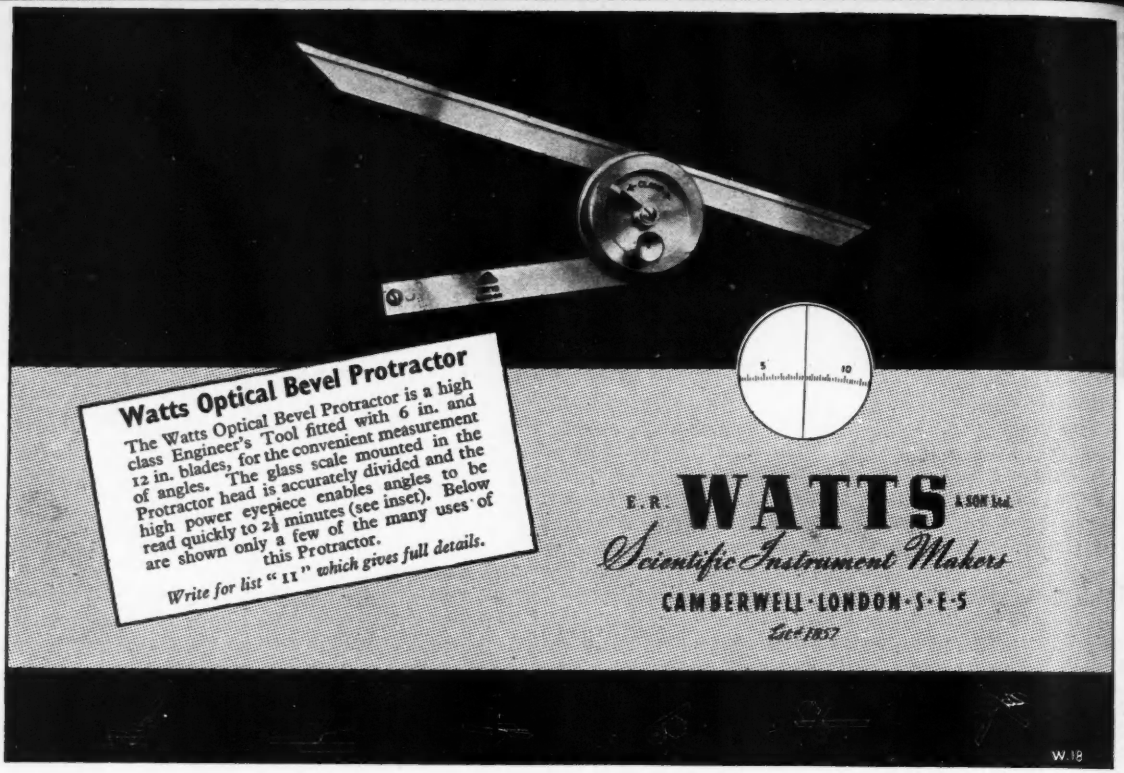
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DISCOVERY

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

Things a Young Physicist should know

THERE was a time when the proper qualification for a professorship of physics was genius at mathematics. That was when what is now known as physics was called Natural Philosophy, and when Natural Philosophy meant part of the syllabus of the Mathematics Tripos at Cambridge. The time is from roughly the middle of the nineteenth century almost to its end. Physics was expanding rapidly to a very considerable extent as the result of the work of mathematicians. Laboratory technique was comparatively simple and could readily be acquired by almost anyone who had the mental agility and flexibility needed for the mastery of the mathematics involved.

It was a system which worked wonderfully in its day, and the period when it was in force includes some of the greatest names in mathematical physics, many of them British, and most of these associated with Cambridge. They include, for example, Clerk Maxwell, who gave mathematical formulation to the laws of electro-magnetism and to the kinetic theory of gases; Lord Kelvin, who put the absolute scale of temperatures on a sound foundation; Lord Rayleigh, who included among his researches the mathematical theory of the scattering of light by the molecules of the air; and towards the end of the period, when physics had already acquired a complex experimental technique, Sir J. J. Thomson, who was a mathematician in the first place, but who is probably most famous for his place in the dynasty of experimental research at the Cavendish Laboratory.

The course of events which led to this state of affairs is easy enough to follow. The great advances made by Newton and his immediate successors were followed in the latter part of the eighteenth century by further advances in mathematical astronomy and physics, but these were mainly made by continental workers. First came the French heirs of Newton, such as Laplace, to be followed by a group who reached their maturity at about the time of Napoleon. At this time, when, in Germany, Karl Friedrich Gauss was making his wonderful discoveries, mathematical physics in Britain was undergoing a partial eclipse. At the beginning of the nineteenth century the heritage of Newton at Cambridge had become too set and formalised for inspiration, and it needed the advent of Charles Babbage and his Analytical Society to set things moving again. The old notation by which differential co-efficients were indicated by dots, instead of, as on the continent, the symbol d, was in current use, and Babbage and his friends choose this as the example of the changes they wished to bring about. His object was, he said, "to introduce the principles of pure d-ism as opposed to the dotage of the University." Whether it was so much his own direct influence, or whether he himself was one of the first influences of the growing industrial revolution, is hard to say. At all events Babbage was far ahead of his time in his application of his mathematical way of thinking to the processes and products of machines. However that may be, the eclipse soon passed, and names like those of John Couch Adams, who computed the position of the unknown planet Neptune, were followed by those of the illustrious mathematical physicists already mentioned.

These men found themselves in close association with what rapidly became the premier mathematical school of the world, and which still to a surprising extent felt itself to be in direct descent from Newton. There was a definitely astronomical influence, for at that time the only practical science at Cambridge was provided by the Observatory, completed in 1824, the Cavendish Laboratory being founded only in 1871. Strangely enough, too, large sections of mathematical physics were, for a time, deliberately excluded from the tripos examinations.

In contemporary scientific thought mathematics was exalted to a very high place. Adams had predicted the existence of Neptune from a mathematical discussion. Hamilton predicted conical refraction on theoretical grounds. Maxwell predicted (although well in advance of their discovery) the existence of radio waves. Taking all things together there was a quite definite implied feeling that once a phenomenon had been put in terms of a few mathematical parameters that was all there was to be said. Naturally enough it was not the great innovators who fell into the traps laid by this view of nature, but those who

removed during restoration this may be done under ultra-violet light in order to maintain precise control of the process.

The condition of the paint itself can be examined by infra-red photography for varnishes, however discoloured in the visible region of the spectrum, are usually transparent to infra-red. Finally, an examination by X-rays may reveal the various strata of paint overlying one another. At this stage many striking discoveries have been made, and much may be learned about the painter's technique. For instance, some artists were in the habit of building up the final picture over elaborate preliminary drawings, and these will show up under the X-rays. Mr. Rawlins cites the example of the side panels of the "Virgin of the Rocks" by Leonardo da Vinci. These side panels both depict angels, and at one time were thought to be by Predis. However, stylistic and other considerations had brought one of the angels under suspicion, and these doubts were confirmed by X-ray examination, which showed that the technique was different in the two cases. One angel is painted over a preliminary drawing: the other shows no trace of this. In other cases X-ray examinations of paintings have shown that the visible picture is painted with something quite different underneath.

Of course, startling discoveries are few and far between, but the routine examination of pictures can always yield valuable information as to their condition and the technique of the artist.

Nor is it always the slightly spectacular results of X-ray examination which yields the important information. The microscopic examination of the surface of the picture in ordinary light often gives results of great importance. The varnish layer may, after the passage of centuries, acquire a characteristic "crackled" appearance, which, on a microscopic scale, reproduces the pattern of cracks which may be seen in the mud of a river bank when thoroughly sundried. This pattern is a good indication of the true age of a picture, for it is almost impossible for the picture forger to reproduce it.

The work of the scientist is thus becoming of increasing importance in many departments of the work of an art gallery. Not least important in these days when invaluable works of art must be stored under bomb-proof conditions is the help which he can give in prescribing the best conditions of moisture and temperature for storage. However, this is a function which will probably have much less fascination for the ordinary man in the street than the processes of scientific detection which infallibly outwit the most expert of fakers.

Contact Lenses

SOME months ago the subject of contact lenses moulded in plastics was referred to in DISCOVERY, when it excited a considerable interest. Briefly, contact lenses are lenses for the correction of defects of the eyesight which are placed in contact with the surface of the eye-ball and beneath the eyelids. They have a number of advantages over ordinary spectacles. They are invisible in wear and are largely protected from damage by the orbital bones of the eye. Now that the plastic form is available the rather remote danger of a direct blow on the eye-ball resulting in splintering of the lens is avoided. From the optical point of view there is the further advantage that more complete correction of eyesight defects is possible by the use of contact lenses than by the use of ordinary spectacles. The focusing action of the normal eye is produced partly by the curvature of the eye-ball itself, and partly by the action of the crystalline lens of the eye. The fact that the contact lens is, as it were, actually a part of the eye enables defects of form to be corrected actually at the site of the defect, but when the optical centres of the lenses of the eye and of ordinary spectacles are separated by some distance the correction can never be so complete for all conditions of vision.

These and other considerations formed the subject of a discussion on contact lenses held by the Optical Group of the Physical Society recently. Two particular defects which are best corrected by the use of contact lenses are first, the serious defect of vision which results when the lens of the eye has actually been removed in an operation for cataract, and secondly, the defect of vision which arises when the transparent part of the surface of the eye-ball (the cornea) is slightly cone-shaped as compared with the normal smooth, flat curve. In the former case what is needed is an additional lens to replace the one removed by operation, and the eye itself is the only place at which anything like a complete correction can be secured. With ordinary spectacles a patient in whom the lens of one eye has been removed, while the other is normal, can never enjoy binocular vision: the images produced in the two eyes are of distinctly different sizes, and when the abnormal eye is turned so that its axis is inclined to the axis of the spectacle lens, the error is increased. The use of a contact lens brings the eye lens and the correcting lens as close together as possible, and these errors of vision can be greatly cut down.

In the case of a conical cornea the contact lens not only corrects the defective vision, but actually helps to mould the eye into a correct shape.

Yet another advantage of contact lenses is that they allow the wearer a very wide field of corrected vision, instead of the comparatively small field afforded by ordinary spectacles.

However, as one of the contributors to the discussion pointed out, contact lenses have their disadvantages too. Many people are seriously upset by the idea of having a lens inserted in their eyes. Others find that they cannot wear the lenses for any length of time, although two exceptional cases were cited in which contact lenses were worn continuously for 24 days and 5 days respectively. Another difficulty which arises, and for which a complete explanation is not known, is the fact that some wearers of contact lenses experience a mistiness of vision, and can see coloured haloes round illuminated objects after the lenses have been worn for a few hours. These defects persist for some time after the lenses have been removed. The explanation seems to lie in a softening of the surface layer of the cornea, but it seems possible that this may be overcome by using a suitable fluid in contact with the eye.

One of the most interesting features of this discussion is the account of the history of the development of contact lenses. The idea seems first to have been suggested by the astronomer, Sir John Herschel, in 1827, who proposed it for the correction of defects of vision arising from irregularity of the corneal surface resulting from injury.

Such irregular defects cannot be corrected by spectacles, but the provision of a contact lens with a layer of fluid between it and the eye-ball fills up the defects and renders normal vision possible. Herschel's original proposal was for a lens filled with gelatine, but in his time optical technique was not sufficiently developed to make contact lenses a practical proposition. Sixty years later a maker of artificial eyes blew a thin glass shell for a patient whose single eye had had to have the lids removed in an operation for the removal of a cancer growth. This shell was successful, but it was designed for protection, not for optical correction. In 1888 Dr. Fick of Zurich used contact lenses in treating cases of conical cornea, but they could not be tolerated by their wearers for any length of time.

In the next year, an ophthalmologist of Kiel, who suffered from short sight, designed for himself a contact lens, and a Berlin optician ground it for him. Optically the device was successful, but unfortunately it could not be worn for more than half an hour at a time. In subsequent work with contact lenses the problem of the blown or ground lens arose. Blown shells of glass were much easier to make, but not accurate enough, whereas ground lenses were far more comfortable to wear. Attempts were made to finish blown lenses by grinding the centre region through which vision would actually take place, to the correct optical figure, but even the Zeiss experts found this impossible and broke all the shells which were sent to them. However, they later improved their ground lenses and produced a better polish. After several other improvements another German optical firm succeeded in 1935 in grinding the correction on blown glass shells, and the feat was repeated by a firm in the United States.

Since that time, moulded lenses have been produced both in glass and in plastics. The latter are slightly more transparent than glass and are lighter in weight, but they are more liable to scratching. However, much of the effect of scratching is eliminated when the surface irregularities are filled with tear fluid on the outside and saline solution on the inside.

A more recent development has been the production of combined glass and plastic lenses. Doubtless, in the not-too-distant future when the war is ended, we shall see a very great development in all forms of this type of visual aid.

The Pilot's Blood

EVERYBODY knows that the crew of a high-flying bomber need to be supplied with oxygen if they are to retain their powers of thought and action. If a man is in an atmosphere where the supply of oxygen is too low his actions become unco-ordinated and reckless, and while believing himself to be perfectly under control he actually behaves with a happy irresponsibility until he loses consciousness. Problems of oxygen need and supply are thus of first-class importance in aviation medicine, and are likely to become more so in the future as higher and higher altitudes are attained.

In ordinary medical practice oxygen is often used in cases of disease or injury to the lungs, and the same kind of detailed knowledge of the optimum conditions of oxygen supply and its destinations in the body, which has

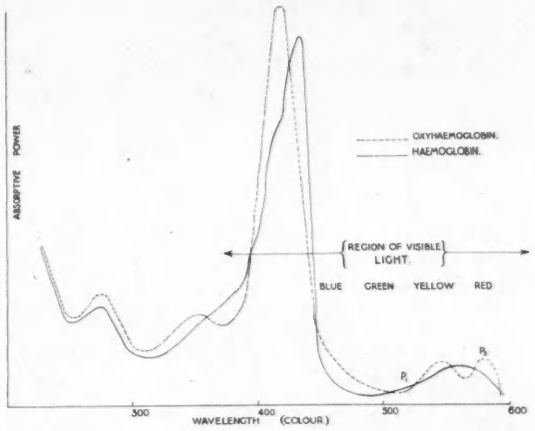

FIG. 3.—Absorption curves of the pigments oxy-haemoglobin and haemoglobin.

been applied in aviation medicine and extended for war applications, is needed to make the best use of oxygen in ordinary clinical practice.

Oxygen is needed in the body to maintain the ordinary functions of the tissues and it is carried to them by means of the blood stream. The blood coming from the heart goes into the lungs, where it is spread out over a large number of small vessels all in contact with the inspired air. There the blood is oxygenated. The pigment, haemoglobin, which is responsible for the red colour of the blood corpuscles, enters into a loose combination with oxygen from the air. This oxygen, riding on the pigment molecules, is carried with the blood stream back to the heart, out into the arteries, then into the arterioles and capillaries, where it becomes available for carrying on the tissue processes. Here the oxyhaemoglobin, as the combination of oxygen and haemoglobin is called, breaks up, and the

FIG. 4.—Diagram to show principle of oxygen meter.

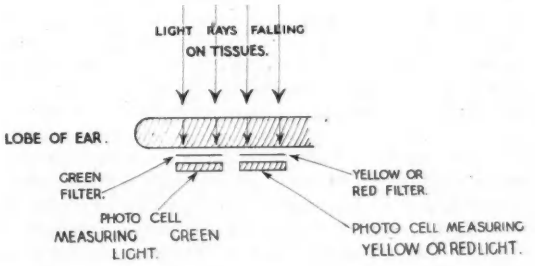
LIGHT RAYS FALLING ON TISSUES.
LOBE OF EAR.
GREEN FILTER.
YELLOW OR RED FILTER.
PHOTO CELL MEASURING GREEN LIGHT.
PHOTO CELL MEASURING YELLOW OR RED LIGHT.

FIG. 5—Instruction in the use of oxygen in a decompression tank. The pressure in the tank may be lowered to correspond to conditions at an altitude of 40,000 feet.

reduced haemoglobin of the corpuscles passes back through the veins to the heart. Thus the blood circulates continuously and its red corpuscles act as oxygen carriers, transferring it from the lungs to the tissues where it is needed.

The colour of oxyhaemoglobin is different from that of reduced haemoglobin, which is the reason why the oxygenated blood of the arteries is a richer red than the blood in the veins which owes its colour to its reduced haemoglobin. This fact is used in a number of devices which have been developed mainly during the war which actually measure the oxygen concentration of the blood of a man while it is flowing in his blood vessels, and without the necessity for puncturing the skin.

The usefulness of such devices is very great. There are very many factors involved in producing a given concentration of oxygen in the blood, which is what counts as far as the efficient working of brain and muscles is concerned. Active exercise produces an increase in the rate of the heart which results in more blood being exposed to the oxygen in the lungs in each second, and so increases the rate at which oxygen is transported to the tissues, which are demanding a greater supply to maintain their activity. But if the oxygen tension in the lungs is too low it may not be taken up by the blood sufficiently fast, which means that if the rate of circulation of the blood is increased, each corpuscle will have less chance to pick up its cargo of oxygen. It may quite well happen that with a low oxygen tension even a great increase in the rate of flow of blood will not result in an increased supply of oxygen to the tissues. This sort of consideration shows the necessity for careful quantitative study of all the conditions of oxygen supply. Simply turning on the oxygen may be useless unless more than a certain minimum is given, but too much may produce undesirable effects.

The design of the instruments for measuring oxygen concentration depends on the fact that the oxyhaemoglobin of arterial blood is of a different colour from the reduced haemoglobin of the venous blood. The crude statement that one is a purer red than the other is insufficient. What is needed is a very exact specification of the two colours. This is provided by curves such as those shown in the figure, which show how much light of each wavelength or colour each pigment absorbs. The curves given are those for the two pigments oxyhaemoglobin and haemoglobin, and are different in some respects from the absorption of the pigments when they are actually locked up in the blood corpuscles, but they will serve as a basis for discussion. The curves show why the pigments look red. Each of them has a large power of absorption in the blue part of the spectrum, so that only the red light gets through. What we are interested in is the part of the curve at the red end of the spectrum. At a point such as P_1 in the green region of the spectrum the two pigments have the same absorption, so that if one took a glass vessel with flat ends containing a solution of a mixture of haemoglobin and oxyhaemoglobin, and then measured how much light of this particular colour got through, one could tell how much pigment altogether there was in the solution. In this region haemoglobin and oxyhaemoglobin absorb light equally well so all one can tell is the *total* quantity of pigment. The process can be illustrated by considering a solution of red ink. If it looks pale pink, i.e. absorbs very little light, there is not much ink in the solution. If it looks deep red there is a lot of ink. With suitable instruments one could make this quite precise and determine exactly how much red ink there was from a knowledge of exactly how much light and of what colours a standard solution of red ink absorbed.

Now if we consider a point like P_2 which is in the yellow part of the spectrum we see that oxyhaemoglobin is a much

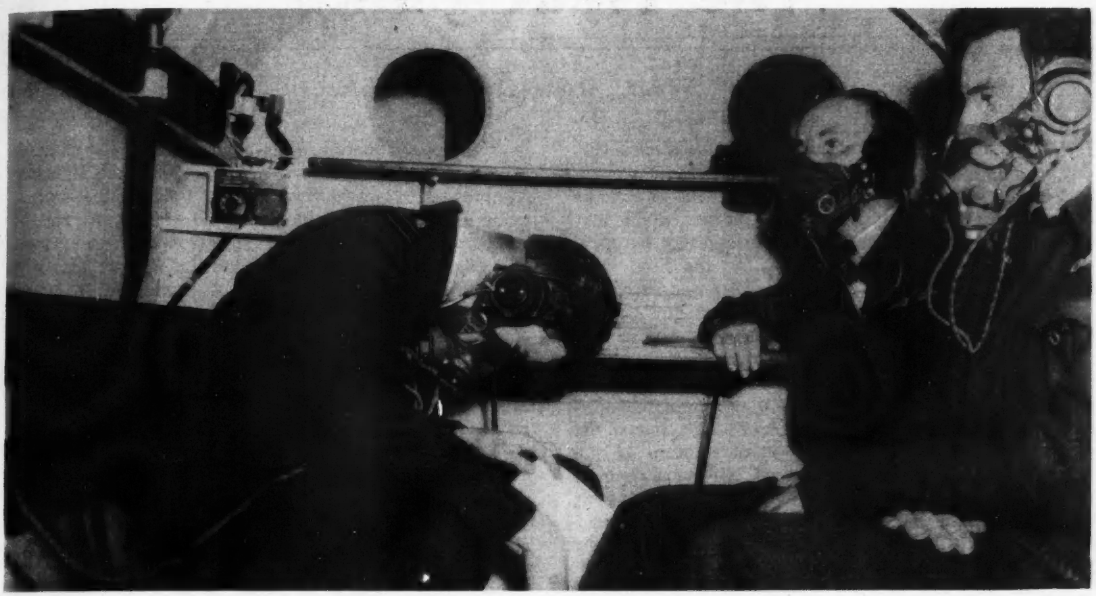

FIG. 6.—What happens when the oxygen supply fails.

better absorber of light than haemoglobin. If we took two vessels of the same size and put solutions of equal concentrations of the two pigments, one in each vessel, we could easily tell which was which because the oxyhaemoglobin would absorb much more yellow light.

The final step is to take a solution of a mixture of haemoglobin and oxyhaemoglobin. Then if we shine green light through it and measure the absorption we can tell how much pigment there is altogether: and if we shine yellow light through it and measure the absorption we can tell how much of each pigment is present.

This is what is needed for measuring the oxygenation of blood. The degree of oxygenation depends on the relative amounts of haemoglobin and oxyhaemoglobin. If we take a layer of semi-transparent tissue such as the lobe of the ear or the web between the first finger and thumb and shine a beam of light through it, the blood in the vessels absorbs some of the light. With colour filters two separate beams of light of different colours, going through the tissues next door to each other, can be separated out (Fig. 2). On the receiving side of the tissues, two photoelectric cells measure how much light of each colour is coming through. One tells us how much pigment of either kind is present: the reading of the other tells how this pigment is shared between the oxygenated and the reduced form. With sufficient ingenuity it is possible to make the machine do the calculation. The best form in which to have the answer is the oxygen concentration expressed as a percentage of the ideal 100% value. The reason for this is that not all the pigment in arterial blood is in the form of oxyhaemoglobin, and not all the oxygen has been removed from venous blood. Besides this, any layer of tissues contains not only arterioles but small veins as well, so that even if the arterial pigment were fully loaded with oxygen, and the venous pigment completely deprived of it, there would still be some of each. This introduces some complications because the readings corresponding to 100% oxygenation will be different for different thicknesses of ear etc., but those who are interested enough to want to go further into this extremely ingenious instrument can read the published accounts of the various types which have been developed in this country and the United States, and which are being used for physiological research in the air forces.

Perhaps the most interesting feature of this work is the way in which it combines the work of the physiologist, the spectroscopist and the electrical equipment designer, who have collaborated to produce one of the most ingenious recording instruments which have appeared in many years.

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The Heat Pump

T. F. WALL, D.Sc., D.Eng., M.I.E.E.

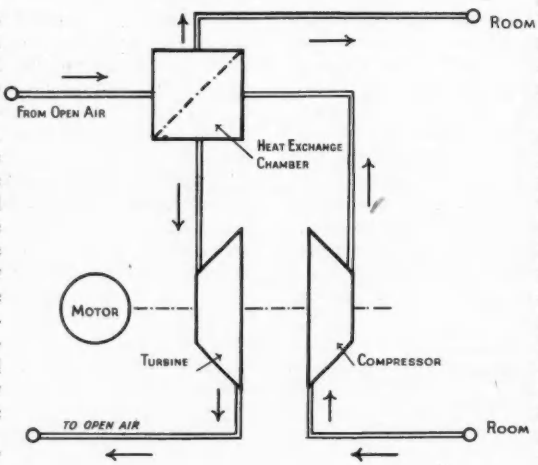
THE fundamental principle of this machine was disclosed by Lord Kelvin in the year 1852, but nothing appears to have been done towards its practical development until quite recent times; and there are several reasons which may be held to account for the delay in recognising the great industrial possibilities of this idea. At the time when Lord Kelvin's suggestion was made there was no special need for such a machine, nor were there any suitable technical facilities available for its construction and application. During recent years however, the principle and application of the heat pump have aroused increasing interest and installations are now in operation in considerable numbers in different parts of the world, one of the most prominent designers and manufacturers of the equipment being the Swiss firm of Brown Boveri & Company.[1] In an article in *Engineering*, for March 19th, 1942[2] the author gave an account of the technical principles on which the heat pump is based and that account forms the basis of the present article.

The extreme and growing scarcity of coal during the past few years has forced communities to seek for alternative natural sources of power and has brought into prominence the significant advantages which are immediately obtainable by means of this remarkable machine. Briefly stated, it may be said that what the machine does is to pump low temperature heat to a temperature level at which it can be used for a wide range of industrial purposes. Large quantities of such low temperature heat are always available everywhere in our surroundings, but they cannot be usefully applied until the temperature level has been raised. For this purpose, electrical power is used, but the amount of heat which is rendered available by the intermediary of the heat pump is many times greater than could be obtained if the electrical power were to be used alone for direct heating, as for example in an electric radiator. At first sight this remarkable result might appear to involve a technical fallacy, but actual practical achievements, some of which are detailed in the following paragraphs, show that there is no fallacy. Before describing the actual arrangements of the heat pump equipment, the following numerical data will give some preliminary idea of the essential scientific facts. Suppose a quantity of dry air at the room temperature of (say) 15·6°C. is contained in a cylinder and is suddenly compressed to one-half its original volume, the process being carried out so rapidly that no appreciable part of the heat developed by the compression has time to pass from the air to the walls of the cylinder, that is to say, suppose that the compression is "adiabatic". Actual calculation will then show that the temperature immediately after the compression will be 109°C. If the cylinder walls are conductors of heat, then the temperature will gradually fall to its original value of 15·6°C.

Now suppose that it is required to keep the temperature of a room above that of the surrounding atmosphere and for this purpose a machine is constructed which takes in air from the surrounding atmosphere, expanding it to lower its temperature, then pausing to allow the temperature to recover its original value by conduction from the surrounding atmosphere. Next, let the machine compress the air so as to restore it to the atmospheric pressure, in consequence of which the air in the machine will become heated above the temperature of the atmosphere, and this warm air can then be injected into the room it is required to heat. The net result of this sequence is that, by expending some mechanical work, a quantity of heat is transferred from the cold atmosphere to the room and the quantity of heat so transferred may be far greater than the thermal equivalent of the work spent in driving the machine.

In Fig. 1 are shown diagrammatically, the main features of such a heat pump equipment for heating and air-conditioning a room. The air in the room, of which the temperature is 20°C., is drawn out near the floor and compressed adiabatically so that it becomes heated to 40°C. It is then passed to the heat-exchange chamber into which fresh air at say 0°C. is drawn from outside, this air thus becoming heated from 0°C. to 30°C. so that the compressed air loses 10°C. of its temperature during the process. The compressed air is then expanded in a turbine so that its temperature falls to - 10°C. and it is then expelled to the outside atmosphere. The requisite mechanical work which is supplied during such a cycle will be the difference between the energy of compression and the energy recovered from the subsequent expansion in the turbine. The fundamental thermodynamical relationships

FIG. 1.—Showing in diagrammatic form the main features of a heat pump equipment for heating and air conditioning a room.



[1] *The Brown Boveri Review*, April, 1942; p. 111; June to July, 1942, p. 190. [2] See also, *Engineering*; April 9 and 23, 1943.

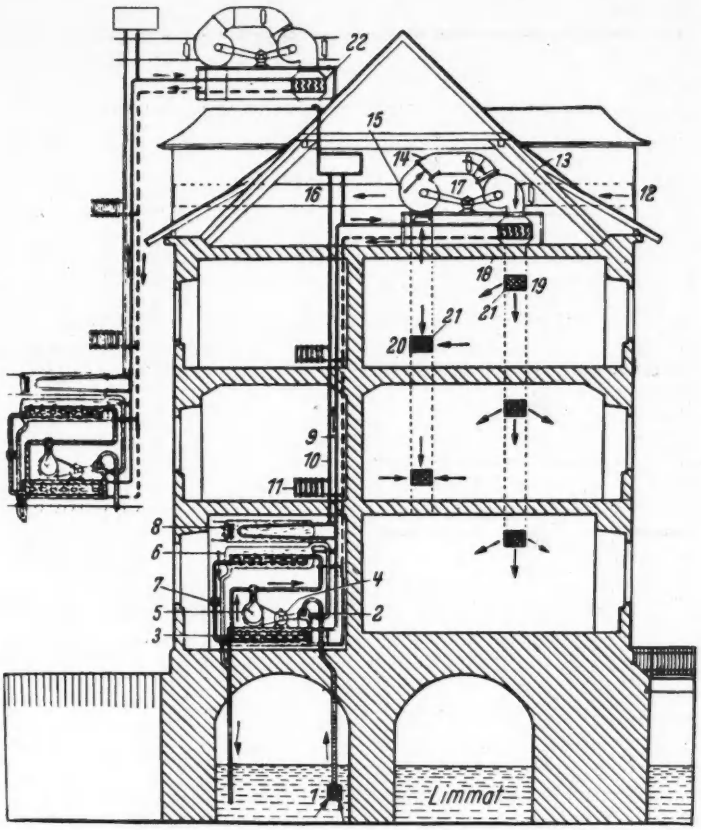


FIG. 2.

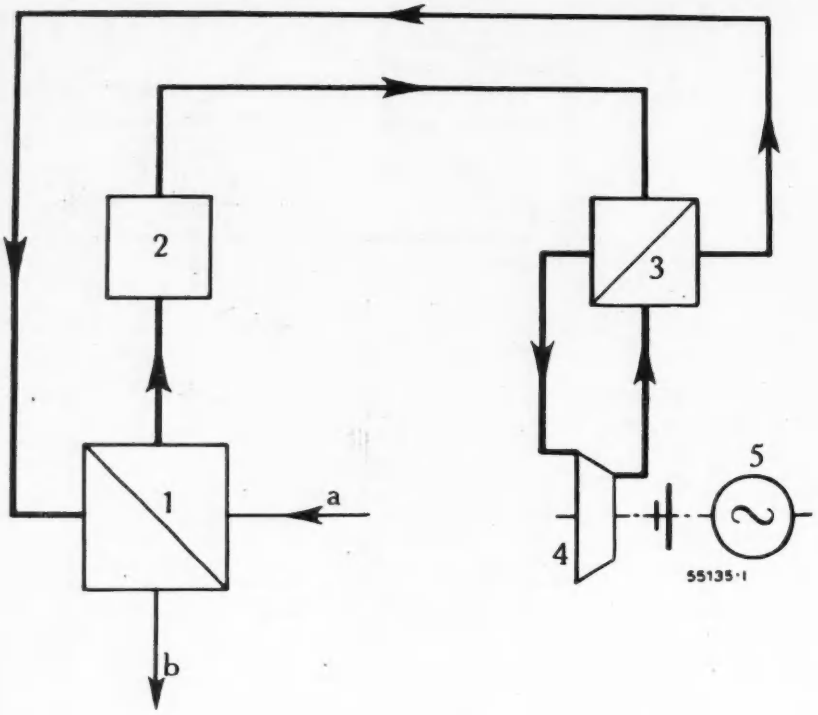
Heat pump equipment in the Town Hall, Zurich, Switzerland. Key to numbered items of the diagram.

1. Suction Grid in R. Limmat.
2. Pulsometer Water Pump.
3. Vapouriser.
4. Motor.
5. Compressor.
6. Condenser.
7. Reducing Valve.
8. Heat Accumulator with Resistance Heater.
9. Pipe for the Outward Flow of Hot Water.
10. Pipe for Return Flow of Hot Water.
11. Radiators.
12. Fresh Air.
13. Fresh Air Ventilator.
14. Air Circulator.
15, 16. Ventilators.
17. Motor.
18. Air Hester.
19. Air Admission.
20. Air Withdrawal.
21. Ventilator Grid.
22. Air Cooler.

which define these processes are well known to engineers and a simple calculation shows that the possibles having obtained by the heat pump operation is very great in comparison with the more normal methods of heating.

It may be said that the installation of a heat pump equipment is technically justifiable when there is a sufficient quantity of water available at a low temperature level and when at the same time, cheap electrical power is also available. A further condition is that the temperature which it is desired to attain is not greater than 70 to 80°C. In addition to its employment for the heating and air-conditioning of rooms, applications are found in various technical processes such as the provision of hot water for drying purposes (e.g. in connection with paper-making machines), for distillation equipments and many other purposes. Very important applications in connection with the food-supply industries are now in operation such as the condensing of fruit juice in a vacuum, the most nutritive parts of the fruit such as vitamins and phosphates being in this way maintained unimpaired since the temperatures used are not sufficiently low to destroy or damage them. Equipments are also in use for the concentration of skimmed milk obtained from the manufacture of butter and this is then converted in a vacuum into powdered milk for use as food. It is also possible to make lactin economically out of serum of milk which is obtained as a by-product from the manufacture of cheese and casein.

The heating equipment which was supplied for the Zurich Town Hall (*Rathaus*) in 1938 is the first large-scale installation of the heat pump principle as a substitute for fuel-fired boilers. In this case, heat is pumped from the River Limmat, the temperature of which varies from about 3°C. to 15°C., and it is then transferred at a higher temperature to a heat-carrier, viz., the water of the central heating system. For the low temperature source, any convenient river, lake, or tank, may be used. The link between the low temperature source and the heat carrier by means of which the heat transfer is effected, is dichlordifluormethane (CH_2 Cl_2) which boils at a temperature of −7°C. and a pressure of 2·5 kg. per sq. cm. The water from the low temperature source is used to evaporate this agent and the vapour is then compressed by means of an electric motor thus raising its temperature to a sufficient degree to allow the requisite amount of heat to pass to the water of the central heating system in consequence of which, the heat transfer agent (CH_2 Cl_2) becomes condensed and flows back to the main container through a reducing valve. Actual test results have since



Key to numbered items of the diagram.

1. Evaporator.
2. Water Separator.
3. Dryer.
4. Compressor.
5. Driving Motor.
   (*a*) Salt Water Inlet.
   (*b*) Distilled Water Outlet.

The salt water is evaporated in 1, then flows through the separator 2, is freed from its last impurities in 3, and reaches the compressor 4 as pure steam. The steam heated in the compressor is first used for drying the absorbed vapour in 3 and then for heating the evaporator 1, after which the condensed steam is drawn off at *b* as distilled water.

FIG. 3.—Mobile Salt Water Distilling Plant for Producing 110 gallons of Drinking Water per Hour.

shown that, for the expenditure of 1 kWh.[1] of mechanical energy, 2000 kcal. of heat become injected into the heating system, it being observed that 1 kWh. = 860 kcal.

In Fig. 2 all the essential features of the equipment are shown and it is to be noted that, during the Summer-time it is only necessary to change over four valves in order to use the equipment as a cooling plant, the operation of the whole system being entirely automatic. The diagram on the left-hand side of Fig. 2 shows the system as operating for Summer-time cooling. Sufficient information of the operating costs of the plant are now available to show that the system has thoroughly justified its installation.

A still more recent equipment is that of the Zurich Swimming Hall which was opened on May 12th, 1941, and some of the leading data of this installation are as follows. The hall has no fireplace or chimney and the total heat supply is provided by means of five large heat pumps each of 92 kW. capacity, two of these being used for heating the water and three for heating the hall. In order to take the peak load and also for use as a stand-by reserve, there is one electric boiler of 2000 kW. capacity. Originally, six coke-fired boilers were installed having a heat production of 440,000 kcal. per hour. Since satisfactory results were then being obtained from the heat pump equipment in the Zurich Town Hall, it was decided to provide corresponding equipment for the swimming hall. In order to increase the efficiency of the equipment, one heat pump is provided to extract heat from the outflow water of the bath (22°C.) and for this purpose, the outflow water of the pre-cleansing equipment (30°C. to 35°C.) is used. With this range of temperature it is found to be possible to obtain 6000 kcal. from an expenditure of 1 kWh. (860 kcal.).

The freshwater supply is at a temperature of 10°C. and this is raised to 28°C. by using it to cool the transformers of the neighbouring sub-station of the Electricity Supply Department. The total annual heat requirement amounts to 2300×10^6 kcal. exclusive of the heating of the hall itself. Of this total amount, 980×10^6 kcal. are obtained from the cooling of the transformers and a further 777×10^6 kcal. by means of one heat pump extracting heat from the waste water of the bath and of the pre-clensing equipment. For this purpose 112,111 kWh. = 105×10^6 kcal. are required so that the multiplying effect or "co-efficient of performance" of the heat pump is

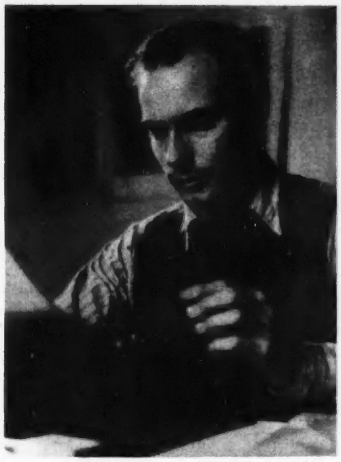
$$\frac{777 \times 10^6}{105 \times 10^6} = 7{\cdot}4$$

[Contd. on p. 272

[1] 1 kilogram-calorie (kcal.) is the heat necessary to raise the temperature of 1 kg. of water through 1°C. One Board of Trade Unit = 860 kcal. = 1 kilo watt-hour (1 kWh).

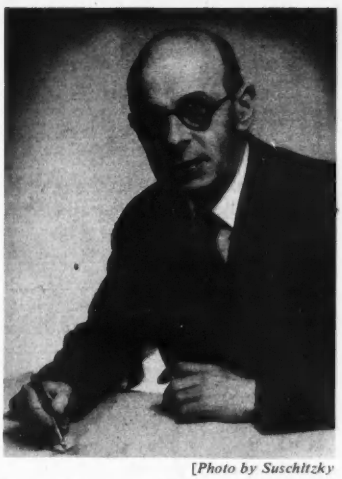
[*Photo by Elliott & Fry*

SYDNEY CHAPMAN, mathematician, professor at Imperial College, London; formerly astronomer at Greenwich. Has worked also on theory of gases, geomagnetism and meteorology. Has travelled widely. Born 1888, married, has four children.



[*Photo by Suschitzky*

JACK CHAMBERS, film director of the documentary school, received his technical training in the G.P.O. Film Unit. Worked for Rotha Productions Ltd. on M.O.I. films. Pre-war work included simple instructional films in physics. Founder member of our film unit DATA LTD.



[*Photo by Suschitzky*

LEWIS RANDOLPH CHAMBERS (father of Jack Chambers) was trained at Goldsmith's College and Heatherley's. Spent many years on the Continent. Has done advertising and film work. At present engaged on designing in plastics for post-war production.

A FILM SCENARIO

UP AND DOWN AND ROUND ABOUT

PROFESSOR S. CHAPMAN, F.R.S. J. D. CHAMBERS L. R. CHAMBERS

There is a story behind this feature. In 1942, Professor Sydney Chapman of Imperial College gave the Kelvin Lecture to the Institution of Electrical Engineers. He amplified some of his ideas on lecture illustration and made them the basis of a script for an instructional film. A few months ago we received the script and asked permission to print it, together with the comments of a film technician, Mr. Jack Chambers. His father, Mr. Lewis Chambers, drew the pictures, which might have been stills if the film had ever been made. The result is a film—or rather a plan for a scientific instructional film—combining the imagination and scientific experience of Professor Chapman (aided by his youngest son), the expert knowledge of practical film-making provided by Mr. Jack Chambers, and four samples of what it might look like on the screen in the hands of an artist like Mr. Lewis Chambers.

SCRIPT *by Professor S. Chapman*

Dialogue between Peter, a young man of twenty-five, and Jack, a boy of twelve (attractive, with good voices).

They appear at first in a garden, with lawn and fruit trees in bloom, and a house showing beyond the trees, and during the rest of the film in a room (Peter's "den") with sports clothes and a cricket bat in one corner, bookshelves, a small lathe, a terrestrial globe, a table and cupboard.

The dialogue continues throughout, without any stop, but the speakers and their scene are not on the screen all the time; other pictures, about which they talk, are shown.

The object is to explain gravitation in the simplest qualitative way; the idea of up and down at the surface of the earth or sun; why the sun and earth are round; and, finally, the contraction and heating of the sun at an early stage in its history.

The whole film to be in colour, except three short runs in black and white to illustrate wrong ideas, the absence of colour here being an additional indication of distinction between them and the right ideas. I found that to introduce and explain these simple ideas about 2,000 words were needed, but possibly a little pruning might still be done. Much of the film would need to be drawn, in the Disney manner.

The script is more suitable for an educational film than for presentation to the general public; but perhaps many parents would find interest in the film, and be attracted by its colour; and as the teaching is given to a character in the film (Jack) they might not feel too much that they themselves were being talked down to.

SCENE I

IN THE GARDEN

Jack is lying on the grass earnestly drawing. Peter enters with a football under his arm.

JACK. Hello, Peter, had a good game?

PETER. Jolly good. What are you doing?

JACK. Drawing a house.

PETER. Let's see.

JACK. Here you are.

Shows the drawing. A close-up of the drawing shows a crude drawing of a house and path, with a square sun in the sky.

PETER. (*laughing*). Why ever, Jack, have you drawn the sun square?

JACK. 'Cause I like squares better than circles. Anyhow, why isn't the sun square? At least sometimes! The moon changes its shape, why not the sun?

PETER. What an idea, Jack!

JACK. Yes, but honestly, Peter, why isn't the sun square?

PETER. Well, if you really want to know, I'll try to explain. Come along to my den.

SCENE II

PETER'S DEN

(*The talk continues as if uninterrupted*).

PETER. You'll see that the sun is round for the same reason that the moon is round and the earth is round.

JACK. That's fine; I should like to understand about the earth being round. I know everybody says it is, and that people have sailed and flown round it. But it doesn't look round to me.

PETER. Well, if there were a tiny fly, say a greenfly, crawling on this globe, it probably wouldn't notice that the globe isn't flat.

JACK. Yes, I can see that the earth can look flat to us because it's so big compared with us.

PETER. Here's a photograph (*close-up shown*) taken from an American balloon that went twenty-two miles up into the sky. You can see that the edge of the land is curved.

Jack turns the globe and puts one hand on England, uppermost, and the other on Australia.

JACK. But what I can't understand is how the people in Australia keep on. (*He looks up and sees a fly walking on the underside of an inverted electric lamp shade*). I know flies can walk upside down, but perhaps they have sticky feet. (*Close-up of the fly on the lamp shade, upside down, winking and doing comic play as it twiddles its legs*). But have the Australians got sticky feet? Don't they get headaches through being upside-down? And don't their loose things fly away? (*Black-and-white picture, headed Jack's* WRONG *idea, shows Australians in wild west hats, walking upside down with sticky feet, and feeling uncomfortable in their heads; the strap of one man's hat comes loose and it drops away downwards. A kangaroo hops into the picture with a baby kangaroo in its pouch. The baby struggles and falls out skywards, and is just rescued in time by its mother's clutch*).

Peter's den then shown again. Jack taps the globe which gives a hollow sound.

JACK. (*continuing*). Or, I say Pete, are the Australians on the inside? (*Black-and-white picture headed. Jack's* WRONG *idea, showing Australians walking upright* inside *a hollow globe*).

PETER. (*laughs*). That's a good one, Jack. No, they're not inside, and they haven't got sticky feet, and their hats don't fly away skywards. Everything of that sort seems much the same as here. I expect Australian boys are as puzzled as you are to understand why we don't fall off, because they know that *they* are standing upright, and as our feet are opposite to theirs, they think *we* must be hanging upside down.

JACK. But it isn't only the Australians being upside down that puzzles me. What about the people nearly half-way round? You'd think they couldn't stop running down, or falling flat on their faces, wouldn't you?

Black-and-white picture, Jack's WRONG *idea showing people slithering forward on the curved sloping surface of the globe.*

PETER. Yes, and if you think about it that way, what about ourselves? You think of us standing on top of the earth just as England is here on top of this globe. But (*turning the globe*) you know the earth is turning about a line called its axis, that goes from the north to the south pole. (*Picture of the unsupported earth turning in space. A dotted line, the earth's axis, flashes into the picture as Peter speaks*). And you see that as the earth turns, England can't remain on top all the time.

JACK. I never thought of that. Yes, that makes it still more puzzling.

PETER. So it is until you realize that wherever you are on the earth things seem much the same. Loose things always go towards the ground, and that's what we mean by falling downwards. Look at Toby on the lawn, racing along. (*Scene of dog rushing across the lawn*). If he went on and on, and could go on running across the sea, right round the world, he'd feel himself everywhere to be jumping up and coming down again just as we see him now, even when he got to Australia and seemed to us upside down. (*Picture of Toby running round a curved world, with the curvature exaggerated; places and scenes marked: the surface curves, and slopes downwards, then becomes vertical, then Toby continues on the underside till he is seen to be running on upside down. This picture headed. "As Toby's journey seems to us". Then another picture, showing Toby running over the same scenes, but always upright, with the earth slipping away behind him. This picture (in colour) headed "As Toby's journey seems to him"*).

JACK. Yes, I suppose he would. But still it's rather hard to understand.

PETER. That's partly because we can't actually see that it is so; we can only see in our minds that it must be so. But draw the blinds and I'll show you a film (*Jack draws the blinds as Peter gets out his film projector*) of the sun that may make it clearer to you. Here on the earth we can only see a bit of the earth, even when we go high up in a balloon. But if we were on the moon we could see the earth as a whole (*picture of the earth slowly turning,*

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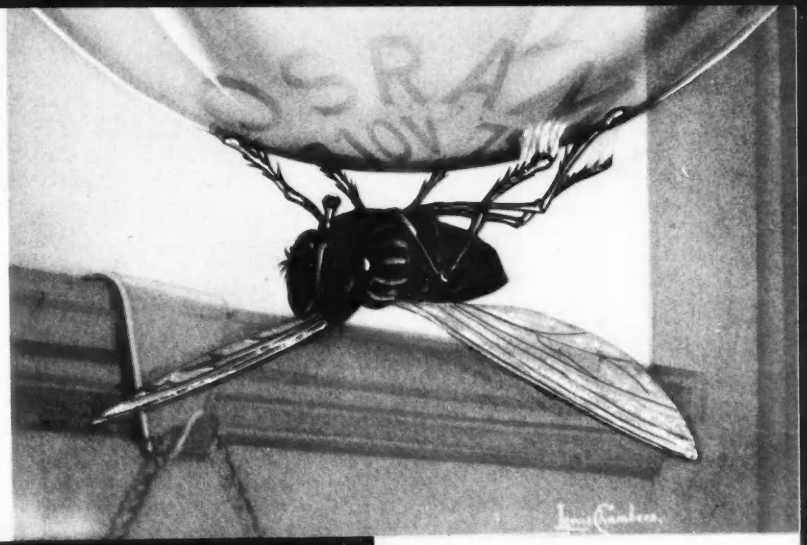

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as seen from the moon) just as we see the moon and the sun—or at least the half that faces us.

JACK. But if we were on the moon could we see Toby skipping along and the people in Australia upside down, ourselves sometimes quite upright and sometimes slanting as the earth carries us round?

PETER. No. Toby and people are too small to be seen from the moon. But on the sun big things happen, and though it's so far from us we can see what look like big explosions, with stuff shot upwards and then tumbling back again. And sometimes we can see this on both edges of the sun at once, with the stuff on the two sides tumbling down in opposite directions, as they do here and in Australia. (*Film of solar prominences in colour.*)

JACK. That's fine. That's lovely. Yes, I begin to see that wherever we are on the earth, up and down only mean away from the earth or towards it, and the same on the sun. (*His eyes fall again on his picture of the square sun. Close-up of it again*). But what about the sun being round? That's what you said you'd explain to me.

PETER. Yes, that's right, and I'm coming to it now. The reason why down always means towards the ground, on the earth, is because the earth pulls us, just as this magnet pulls this bit of iron. (*Close-up*). If I lift you up (*does so*) I have to push upwards because the earth is pulling you downwards. You can't feel that it's the earth that's pulling you, any more than the bit of iron feels that its the magnet that's making it move—or, if we hold it fast, that makes it try to get towards the magnet, just as you're pressing down against my upward push. What we call your weight means the earth's pull on you, just as the weight of the stuff falling downwards on the sun is the sun's pull on it.

JACK. Yes, I see. Go on.

PETER. Well, this pull on things near the earth, or near the sun, makes everything get as near the centre of the earth or sun as it can. This wooden cube on the table can't move sideways to slip down, nor can it change its shape. It stays just as it is. But if I had a cube of pitch here, instead, and left it long enough, it would gradually flatten out—the sooner if the sun were shining on it and softening it. (*Close-up of a lump of pitch flattening out*). The pitch is something between a solid and a liquid; it can flow but only very slowly. Water can flow easily and when the sea throws up a big wave (*sea picture*) the earth's pull soon flattens it out again.

JACK. Yes.

PETER. The earth pulls the air too, and holds it down so that it doesn't all stream away into the sky. The pull on the air higher up, that is, the weight of that air, presses on the air below, and compresses it. On a very high mountain, like Everest, the air is much thinner than it is here, because there is so much less air above it pressing it down. That makes it difficult for climbers (*Picture of mountain climbing on Everest*) and still more for the Americans who went twenty-two miles up in a balloon; *they* had to have an airtight chamber and their own oxygen supply; they couldn't have lived in an open balloon basket at that height. Our airmen too, who fly very high in aeroplanes, have to take with them special breathing apparatus. (*Close-up*).

JACK. I suppose the earth's pull keeps the air level all round the earth?

PETER. Yes; and the same on the sun, which indeed is all air of a sort. It is a great glowing globe of air or gas (not coal gas), and being very big it has a very strong pull. This is what keeps it round, because if some part jutted out, like a great wave or a big outstanding corner as on this cube, the pull would soon draw it down to the same level as elsewhere.

JACK. I think I see now.

PETER. This may perhaps help you. Look at these little balls of quicksilver out of this broken thermometer. (*Pours some mercury out on a saucer : close-up*). They keep a round shape because they too have a sort of pull inwards all over their surface. See, if I shake them or poke them out of shape they quickly become round again.

JACK. Well, I understand now why the sun is round, because it can change its shape easily (not like the wooden cube) and yield to the pull towards its centre. But the earth is solid and the mountains (*picture*) can stand up on it. Why is the earth round?

PETER. Ah, that's because the earth too was once a hot globe of gas, and so could then take a round shape easily, like the sun. Later it became less hot, and condensed to a liquid, just as steam condenses to water. But the earth was not just water, it was molten rock; then it cooled and became solid, just as molten lead or glass become solid when they cool.

JACK. Then why isn't it quite level? Why are there mountains on it?

PETER. That's an interesting question, and perhaps we'll talk about it another day. But now I want you to see this other film, that will show you how the sun became hot.

JACK. Why, wasn't the sun always hot?

PETER. No. Millions of years ago it was cool and didn't shine at all. There were no people then, indeed no earth, but if there had been we shouldn't have known the sun was there. On the earth it would have been always night, with only the stars shining.

JACK. Then what made the sun shine as it does now?

PETER. It was because of that pull we've been talking of. The sun was once enormously bigger than now, but all the time it was steadily pulling inwards, just as the earth is pulling the air and holding it down. Here on the earth the land and sea stop the air from moving inwards any further. But the sun is all air or gas, and there's nothing solid to keep it from yielding to its own pull, and so shrinking in size. Thus it kept becoming smaller, and the gas got more and more compressed; and as it did so, it became hotter."

JACK. I know; when I pump up my bike tyres the pump gets so hot sometimes that I can hardly hold it. I suppose it gets hot because I have to compress it so much before I can push it through the valve. (*Peter getting his projector ready*).

PETER. Yes, that's right. And in the sun the gas got enormously compressed, so that it grew bright, as if it were burning. This happened first at the centre, where the pressure was greatest; but as the sun kept on shrinking, more and more of the gas inside it got hot and bright. See, this film shows you how the inside of the sun would have looked if we could have cut it in two like an orange.

JACK. Is that the sun in the middle with the thin line round it?

PETER. Yes; but that line shouldn't really be there, because the sun was quite dark.

JACK. Oh, see, it's beginning to glow in the centre. It's just the colour of the poker when I stick it into the fire and take it out pretty soon. See, now it's getting brighter; it's yellow in the middle now. There, it's getting white-hot; and how much smaller it is. Could people (if there had been any!) have seen that hot bright part inside it?

Here comes a coloured film of the contracting sun, showing as a continuous process the passage through the stages illustrated in the coloured pictures shown at the Institute of Electrical Engineers in 1942, *and later at the Royal Astronomical Society.*

PETER. Only very dimly; the dark gas on top would hide the brightness from view, just as thick clouds sometimes make it nearly dark for us even near noon.

JACK. Ah! the light has got to the outside now; and that's getting hotter too, it's turning from red heat to yellow heat, the actual colour of the sun.

PETER. Yes; and now we'll have that last bit over again, but as seen from the outside, not as if the sun had been cut open. Here it is.

JACK. That's fine. But what are those dark spots on it?

PETER. Those are sunspots. Someday I'll tell you about them too, and how they sometimes upset our cable and telegraph and radio companies. But that's enough for now. (*Draws the blinds and let daylight again into his room. Jack sees his picture again, picks it up and begins to rub out the square sun*).

PETER. What are you doing, Jack?

JACK. I think I'll make my sun round after all.

CRITICAL REVIEW *J. D. Chambers*

Is a popular exposition of the law of gravity ideal material for an instructional film?

The cinema screen is perhaps the most versatile medium for propaganda or instruction, but it is not the only one and cannot be expected to serve every purpose. I begin with this mild warning because I am writing in the hope of stimulating the production of popular educational films; but not by specious arguments that film is the "modern" medium, is "universal in its appeal", irrespective of whether the subject is more suited to other means. Some are best dealt with by radio, some by an exhibition, others through the pages of DISCOVERY, etc. It should be recognised that each medium has its range of suitable material and a roughly definable audience.

Special Properties of Cinema

The cinema is able to reproduce visually, and in some cases to make visible for the first time, almost any type of movement—at a true or at a translated speed. It is able, by the process of "cutting," to bring objects to a common relationship on the screen. And from a combination of its ability to enlarge with the two-dimensional nature of the screen, it is able to give an almost identical view of an object or process to all members of an audience.

This is perhaps a rather dry way of describing those potentialities which are used to such exciting and dramatic purpose in the films we see every day. It covers the amazing artistry of Disney's cartoons: the flashing speed of Donald Duck, logically leaving a trail of smoke from the friction of his passage!—the delicate tip-toeing of the villainous wolf, the heroic jumps over impossible spaces—these which we see as real as life are all movements which have never occurred in reality. They are made visible for the first time only after the film has been shot.

It is a thrilling experience when the "rush prints" of an animated film come through for projection. One sees movements come to life which until then have been only a series of still pictures which one laboriously shot frame by frame, from a pile of dead "cells".

I am glad indeed to see Professor Chapman introducing cartoon technique into his script.

It covers, too, translation of motion; speeded motion of which Percy Smith is the master and which can be seen in the "Secrets of Nature"—the beautiful movement of a sprouting lupin, graceful roots thrusting deep into the soil, delicate plant structure rising from the surface and waving cyclically as the flower orientates itself to the sun. And the well-known slow-motion, which has been developed to such a pitch that to-day it is run-of-the-mill to shoot at 200 times the speed of projection.

And covered also is the dramatic editing of films such as Paul Rotha's "World of Plenty" in which scenes of food being burnt and thrown into the sea are directly related to the starving negroes and poor whites of the southern states.

These powers which I have defined above make the film particularly suitable for describing dynamic processes. It probably is the best medium for explaining gravitation after all.

The Audience

Before starting on even the preliminary stages of scripting it is important to decide on the audience for the film. This may sound rather like counting your chickens before they're even fertilized, but in fact every detail of film making is controlled by the audience for whom the film is finally intended. And here arises my first general criticism of Professor Chapman's script: it seems to me the audience has not been selected; even that no real audience has been in mind at all.

The Scientific Films Committee of the Association of Scientific Workers has been working for some years on the classification and appraisal of scientific films, and has formed a useful working definition of audiences in three groups:

(1) General; cinema or public non-theatrical audiences.
(2) Teaching; classroom or other educational audiences.
(3) Specialist; technical and research workers and students.

Too many films attempt to cater for more than one audience group and so fail to serve any one properly. Each film should be planned from its inception for at least as restricted an audience as one of the above groups.

But don't interpret this in a negative sense, films for teaching must not become dull, nor specialist films unnecessarily complex or obscure.

It might be argued that a film could be made with no expectation of an audience at all, but as a matter of economics this is very unlikely—there will be some audience if it is only the foundation which provided the funds!

To supply this economic necessity, and to give us a "target area" for the film let us choose say Group 1—General cinema and non-theatrical audiences. This offers the advantage of numbers. If the film is successful it will be seen by audiences totalling millions, composed of people unlikely to get this sort of knowledge in any other way.

On the other hand there are disadvantages. We have to compete with Popeye and the Newsreels for the attention of the people. They will not be in a mood to exert themselves to gain knowledge. They will be an audience untrained in logical deduction, and there will be none of the discipline of a classroom. In the classroom too the film can be stopped, reversed and so recapitulated, the lecturer can explain difficult points but in the cinema there are none of these possibilities. Facts and arguments must be grasped as they are stated. Analogies must be sorted out while the film is already travelling on to the next illustration.

Subject Matter

Unfortunately very little scientific work has been done on the psychology of audiences; there is a tremendous field here for investigation. Working in film production we can only arrive at empirical conclusions, which become our rules-of-thumb. The first is, that about a tenth of the material in a film—its statements, its illustrations, its deductions and conclusions—is retained in the minds of the audience.

This might seem at first sight an argument for cramming in as much as possible; but, as you would expect, this is fallacious. The real aim should be to see that it is the right tenth which is remembered. The interesting result is that perhaps 90% of the film must be planned not to be remembered but to point the meaning of the important 10%.

Considering Professor Chapman's script with this in mind, and having chosen "General Audiences", I feel that there is material here for two films. The first would deal with the facts of gravitation, including the comparison between the sun and the earlier state of the earth. The second would deal with the contraction and heating of the sun. As remarked by the character Peter ". . . . see this other film that will show you how the sun became hot." This would leave room to answer such questions as "Why are there mountains on the earth" in the first film, and to amplify the information about sunspots in the second. As they stand these references lead the audience away from the central themes and they should either be answered or cut out.

Treatment

Having selected the general public for our audience and limited the subject matter accordingly, let us look at the script and see how it would be treated professionally if it were being made for, say, the Royal Astronomical Society.

At this stage the script is called a "treatment", the shots would not yet be defined technically and the matter would be written in narrative style.

The title stands for the present. It becomes the "working title" and is likely to be altered only at the last possible moment.

As we are setting out to make the film for a definite audience the need disappears for the imaginary one in the person of Jack, the twelve-year-old boy. This will avoid the suggestion that you consider the audience to consist of twelve-year-olds. The film projector within the film goes along with Jack, it is a cumbersome device at best.

What we have to say is now said directly to our audience. The language we frame it in, visual and spoken, is determined by their understanding, which is not that of a twelve-year-old, an ancient fallacy which Hollywood has long since unlearned. Talking down to the audience will always arouse justifiable resentment.

The material is tremendously interesting in itself; it needs no sugar, only a good clear style and sympathetically chosen visuals. Professor Chapman's visuals are delightful and should certainly be kept: perhaps the "mistaken ideas" are portrayed a little too attractively—they might stick too well!—but that could be adjusted in the script.

Scene I no longer has any purpose; the treatment would open with the relevent arguments of Scene II, set out something like this:

Treatment for a General Instructional Film on the Law of Gravity

Working Title

"UP AND DOWN AND ROUND ABOUT"

Sequence I

A delicately constructed model globe, with raised contours is shot close up, against a background of clouds to give the impression of a stratosphere plane's view.

The commentary begins:

"Here is our world: But to see it like that you would have to be as far away as the moon".

"How do we know it really is like that?—a globe, hanging in space?"

The scene changes to a shot at the earth's surface on a wide plain, say an aerodrome with a plane taking off.

"From our more usual viewpoint our world looks pretty flat, though we know people have flown and sailed around it."

Scenes from the plane of land and sea, accompany this

"and even from a plane you can't see much 'globe' about it—until you get up really high—"

Here, come the still photographs taken from the stratosphere balloon,

"These photographs were taken from a balloon that

went up twenty-two miles over the United States. At that height the world really begins to look round".

The scene changes to a model of the solar system, planets circling the sun, the moon, the earth, etc.

"And if you look in the sky you find that we are living in a universe of globes."

Well, already we have reached Professor Chapman's visuals and in this style I think the film should continue with them. The "men (and kangaroos) down under"—the sticky flies, and Toby the dog running round the globe, I wouldn't change any of them.

In this short section of treatment I have tried to show the unimportant 90% leading up to the decisive 10%; in this case the photographs taken from the stratosphere balloon. The take-off from the aerodrome, the aerial shots of land and sea should give the impression of greater and greater height above the earth, so that the stills become really convincing and can be followed by the generalising model shot of the solar system.

There is one technical difficulty which would arise: in filming the script as it is, black-and-white and colour cannot be alternated in the same reel of film.* A choice would have to be made of one or the other. One more point: the indiscriminate mixing of real shots with cartoon might upset the smooth flow of the film; it is something of a shock to change from actuality to cartoon, and that shock could be put to some purpose, say, by making all the mistaken ideas cartoons and all the right ideas actual shots.

One final warning to those who wish to go into production with an ambitious programme of instructional films: of all the media for spreading knowledge this is the most expensive. The lack of any large number of such films is a measure of the difficulty in getting finance for them. So all success to those who are out to fill the gap, but if after struggling to get funds you find them suddenly offered too freely, watch out for the strings attached to them!

[Professor Chapman's comment upon Mr. Chambers' Critical Review of his script is that he agrees that it should be made into at least two films, but that he regrets the disappearance of Peter, Jack, and the "machinery".]

*For this reason the stills of "wrong ideas," which according to Professor Chapman's script should have been black and white, are shown in colour in the accompanying illustrations.

HEAT PUMP—*(contd. from p. 266).*

The remaining 540×10^6 kcal. has to be obtained by means of a second heat pump utilising a source of cold water the temperature of which varies from 2°C. to 20°C., the sum total of these three components being $(777 + 540 + 980)\ 10^6 = 2297 \times 10^6$ kcal. as already stated.

The expenditure of energy on the second heat pump is 155×10^6 kcal. so that the co-efficient of performance in this case is only $\frac{540 \times 10^6}{155 \times 10^6} = 3{\cdot}5$

This relatively small value being due to the wider range of temperature through which it is required to operate.

The whole equipment may be said to have fulfilled all expectations and it is considered that it will promote a greatly extended use of the heat pump principle by other authorities who are in charge of establishments for which such a method of heating is suitable.

In Fig. 3 is shown a diagrammatical representation of a mobile salt-water distilling plant for producing 110 gallons of drinking water per hour.

A technical paper published in 1928 by T. G. N. Haldane emphasised the practical possibilities of the heat pump principle and aroused interest in America. The stage of development which has now been reached is due to prolonged series of experimental investigations in America and Switzerland and it is probable that the lack of coal resources in Switzerland has been largely accountable for the prominent part which that country has taken in these developments.

The climatic conditions of a country have a definite bearing on the question of the suitability for the operation of the heat pump in that country. For example, in England the air temperature rarely falls below 40° F. and for a substantial period of the year it is above 50°F. For these conditions, calculations show that room heating to 70°F. could be performed for a substantial part of the year with a theoretical co-efficient of performance of 20, whilst for the heating of bath water this co-efficient is about 10 and for the boiling of water, about 4.

The Los Angeles Offices of the California Edison Company are heated (and cooled) in this way, and in a specific case, where the outside temperature was about 48°F. and the inside temperature of the building was maintained at 70°F., the actual co-efficient of performance obtained was just a little over 2 as compared with a theoretically possible value of more than 20.

It is clear from these results that there is still immense scope for further development work and few industrial undertakings can claim to be of more general natural interest and importance in view of the remarkable saving of fuel which such means as the heat pump renders possible.

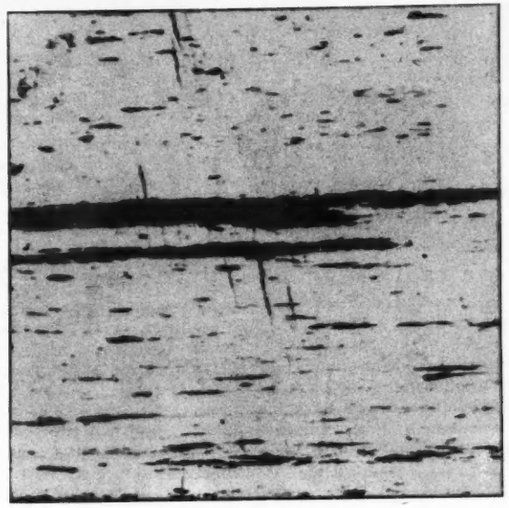


FIG. 1

How does Coal become Coke?

H. L. RILEY, D.Sc., A.R.C.S., F.R.I.C.

IN the investigation of coal structure, X-rays have been used in two fundamentally different ways, viz., (1) in the manner of the medical radiographer, and (2) by making use of the diffraction phenomena which occur when these short electro-magnetic waves impinge upon a more or less highly ordered array of electrons. The former method has been used to study the distribution of ash in coal, particularly by Šimek, who, before the war, directed the flourishing Coal Research Institute in Prague. Fig. 1 is a reproduction of one of his radiographs; it shows the distribution of ash in a piece of anthracite, perpendicular to the bedding-planes. Information of this kind is of importance in connection with coal cleaning. The radiographic method has also been used at the Fuel Research Station (D.S.I.R.) to study the micro-crack structure of coal. The coal is first soaked in an aqueous solution of lead acetate which percolates into all the small cracks. The heavy lead atoms absorb X-radiation to a greater extent than the lighter atoms in the coal and the radiograph therefore shows quite clearly the micro-crack structure and provides information of importance in the study of coal breakage.

The second method of using X-rays to investigate the structure of coal is not so easy to understand, for it is concerned with the molecular structure of the coal. Discoveries were made some 30 years ago—(their importance has not yet perhaps been fully realised)—by M.v. Laue and by W. H. and W. L. Bragg, concerning the diffraction of X-rays by crystals. The interesting phenomena observed by these scientists not only gave a much deeper insight into the nature of X-rays, but also provided a means of obtaining detailed information concerning the manner in which the atoms of solids are packed together. During the nineteenth century and the first decade of the twentieth, considerable progress was made in the elucidation of the structure of simple molecules, but knowledge concerning the structure of solids, particularly those of importance in everyday life, e.g. metals and alloys, wood, textile fibres, foodstuffs, rubber, coal, etc., remained largely speculative. There is a simple reason for this: classical chemical methods require that the substance under investigation shall be a pure, single molecular species and that it shall be either liquid or soluble in some liquid, or vaporisable without decomposition, i.e. purely chemical methods only permit its investigation in the liquid or vapour state. Conclusions drawn from data obtained in this way regarding the structure of solids were frequently incorrect and misleading. X-ray diffraction studies of solids have already provided a mass of new information, which has not only corrected older ideas, but has given us a deeper insight into the atomic and molecular structure of solids, which is of great theoretical and practical importance.

Before describing the particular method which has been used in studying the structure of coal, it is necessary to say something about the formation of coal.

How Coal was formed

Palaeobotanical investigations have shown that coal has been formed from vegetable débris. Most of the coal deposits in the British Isles were originally laid down in carboniferous times, probably some 200 million years ago. The vegetable débris was first converted into peat, then into brown coal and lignite: these "young" coals were slowly transformed into bituminous coal and finally into

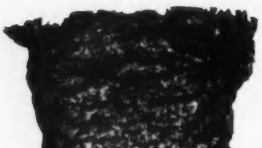


FIG. 2a—Bitumen Coal (Swelling No. 9)

FIG. 2b—Dibenzanthrone

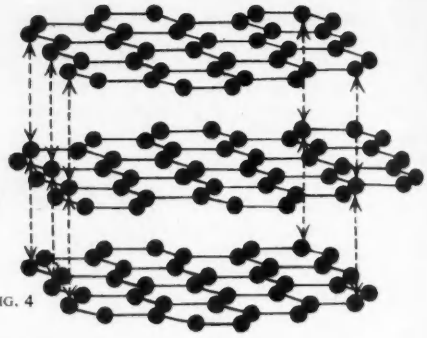


FIG. 4

anthracite. Chemical and statistical evidence indicates that the transition from peat to anthracite is a continuous one; it is accompanied by a gradual increase in the percentage of carbon in the coal, a decrease in the percentage of oxygen, carbon dioxide, methane and water being evolved during the process.

The continuous change which during Geological time has progressed at a rate depending on local conditions of temperature, pressure, etc., i.e. the gradual increase in the rank of the coal, is accompanied by a curious phenomenon. If we took about one gram of a finely divided, low-rank, bituminous coal containing about 80% carbon, and heated it rapidly over a bunsen flame in a closed silica crucible, we should find on cooling that the residue consisted of a powder of more or less pure carbon. A similar experiment carried out with a coal of somewhat higher rank, say about 84% carbon, would probably give, instead of a powder, a more or less swollen, coherent button of coke. With a coal containing about 88% carbon, particularly if the coal was a bright coal and had been obtained from certain seams, we should obtain a coherent, highly swollen coke button similar to that shown in Fig. 2. If now we employ a coal containing about 92% carbon, i.e. a semi-bituminous coal, we should find that a non-coherent powder remained in the crucible.

These phenomena of caking and swelling are of importance in the manufacture of coke, particularly of metallurgical coke, for on them depends the possibility of obtaining a hard, strong coke, suitable for use in a blast furnace. Weak, friable cokes cannot be used, for they would break down under the weight of the burden in the shaft, and the small coke produced would clog the furnace and prevent it working efficiently; in fact, instances are known in which it has been necessary to shut down furnaces because of the use in them of inferior varieties of coke.

It is therefore important to know something of the coke-forming characteristics of coals and also of the molecular phenomena which determine these characteristics. The caking and swelling of coal are also of importance when the coal is to be used directly for raising steam; they often determine the type of boiler and mechanical stoker best adapted for the utilisation of the particular coal.

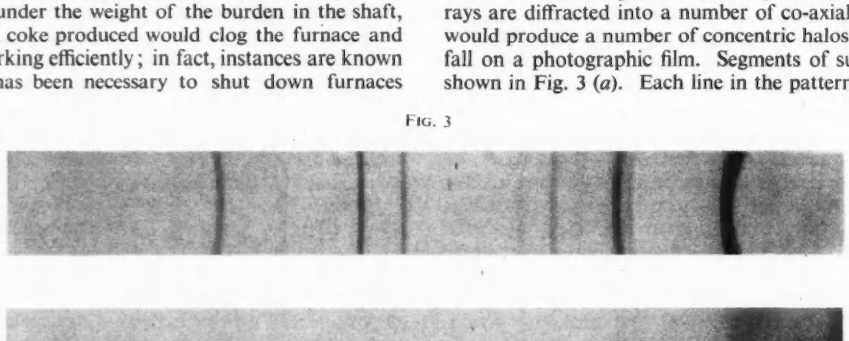
Several theories have been put forward to explain the caking and swelling phenomena described above. Some workers have supposed that they are due to the presence of "coking constituents" that have been formed in the course of geological time from the nitrogenous compounds originally present in the vegetable débris, whilst others have suggested that the original vegetable resins are responsible. Neither of these views is supported by experimental results. X-ray diffraction investigations carried out in the Northern Coke Research Laboratory, King's College, Newcastle-upon-Tyne, have indicated the lines along which we must look for an explanation.

The Structure of Graphite and Carbon

Bituminous coal is a highly complex substance, and it is therefore reasonable, before discussing the more difficult problems of coal structure, to say something of the structure of similar but much less complex substances, viz., graphite and "amorphous" carbon.

If a narrow pencil of monochromatic X-rays is allowed to fall on a small specimen of finely divided graphite, the rays are diffracted into a number of co-axial cones which would produce a number of concentric halos if allowed to fall on a photographic film. Segments of such halos are shown in Fig. 3 (*a*). Each line in the pattern corresponds

FIG. 3



with a family of parallel planes of carbon atoms in the graphite crystal lattice. From photographs obtained by this and other similar methods, Bernal, in 1924, worked out the structure of graphite shown in Fig. 4. The lattice consists of a series of parallel layers of carbon atoms stacked in an orderly manner at intervals of 3·4 Ångström units (1 Å.U. = 10^{-8}cm.). Within each layer-plane the carbon atoms are arranged in a honeycomb pattern, the C-C spacing being 1·42 Å.U.

Thirty years ago it was thought that the element carbon existed in three allotropic modifications, two crystalline—diamond and graphite—and one amorphous. In 1917, however, Debye and Scherrer made X-ray powder photographs of black carbons obtained from the following sources: (1) from sugar by melting, coking and heating, (2) from acetylene by incomplete combustion, (3) from naphthalene by incomplete combustion, (4) from petroleum by burning, (5) from sucrose and concentrated sulphuric acid, (6) from retort carbon, and (7) from anthracite. All these carbons gave essentially the same diffraction picture, similar to that shown in Fig. 3 (*b*), the diffraction maxima always being in the same place; it was concluded from these results that amorphous carbon is really only graphite in an extremely fine state of subdivision. In Fig. 3 (*b*), instead of several sharp lines we see only two diffuse bands; this is because the individual crystallites are extremely small. They are similar in structure to the graphite crystal lattice, but contain only some four or five honeycomb-like layer-planes of carbon atoms which are about 30 Å.U. across. If another layer-plane was added to Fig. 4 and the layers themselves approximately doubled in size, it would present a vague, average picture of one of these carbon crystallites. The individual layers are stacked parallel to each other, but are otherwise quite disordered. By measuring the breadths of the photometer traces of these diffuse halos, it is possible to obtain average values for the dimensions of these small crystallites. The greater the breadth, the smaller the crystallite. Usually there are only two halos in photographs of this kind, and it is therefore necessary to picture the carbon crystallites as small cylinders, with the hexagon layer-planes parallel to the base of the cylinder. The inner, more intense, halo gives us the average height of these cylinders (*c* dimension) and the outer, less intense halo, the average diameter (*a* dimension).

A single X-ray powder photograph of an "amorphous" carbon does not give us a great deal of information about its structure. We only learn from it that the carbon consists of exceedingly minute crystallites which possess a graphite-like structure and certain exceedingly small dimensions. If this was all we could learn about carbon it would not be of much help with regard to the problem of coal structure. Fortunately other avenues of approach are open; there is, for example, an enormous amount of material available for experimental investigation. Carbon can be prepared by charring many different organic compounds, coals, and other carbonaceous materials, and the products subjected to detailed chemical and X-ray examination; the rate and temperature of carbonisation can also be varied and the effects studied. Investigations of this kind have brought the following interesting new facts to light.

Chars prepared from cellulose, with extreme variations

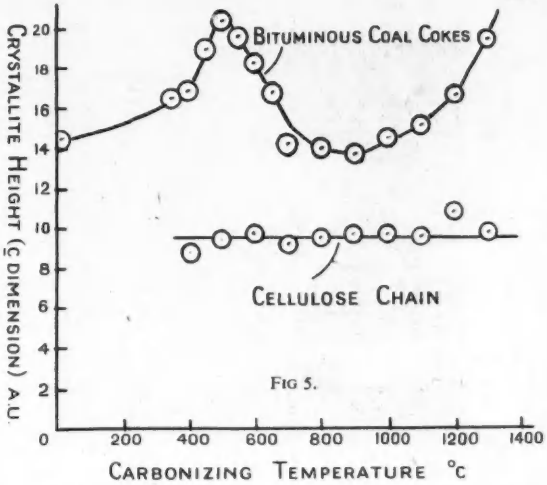


Fig 5.

of carbonising conditions with regard to temperature (400°C. to 1200°C.) and rate of heating, always contain crystallites with the same average *c* dimension (height) of approximately 10 Å.U. The same result is obtained if instead of cellulose we char glucose, starch, sugar, lignin, wood or fusain (mineral charcoal). The result is always the same; no matter what the rate of heating or the final temperature is between the above limits, the inner halo of the X-ray powder photograph is always the same. This indicates that the above picture of the carbon crystallite is incomplete; if the hexagon layer-planes are held together only by weak molecular forces, as is the case in graphite crystals, then we should expect them to pack together to a much greater extent when subjected to intense thermal vibration. A *c* dimension of 10 Å.U. indicates that on the average each crystallite contains only about 4 layer-planes: it is, however, the constancy of this *c* dimension which is the surprising new fact, for it suggests that the layer-planes are cross-linked, in some way, by powerful valency forces.

This result is made all the more surprising when similar experiments are carried out with bituminous coals, for, instead of obtaining a constant *c* dimension we find systematic variations with carbonising temperature. Fig. 5 shows typical *c* dimension curves for cellulose chars and for bituminous coal cokes. Young coals (peat, brown coal and lignite) show an entirely different behaviour, which cannot be discussed here. It is the study of these *c* dimension variations which has led to a much deeper insight into the nature of bituminous coal.

Nature of Coal Bitumens

The X-ray diffraction photographs of coals themselves show certain important characteristics which are very closely connected with this variation in the *c* dimension. It is possible to break up coal into various fractions by extraction with such solvents as pyridine and benzene. If a bituminous coal is thoroughly extracted with pyridine, and the residue (α fraction) carbonised, it is found that the *c* dimension curve no longer shows the pronounced maximum at 550°C., but gives a curve which is either horizontal or falls with increasing carbonising temperature. The

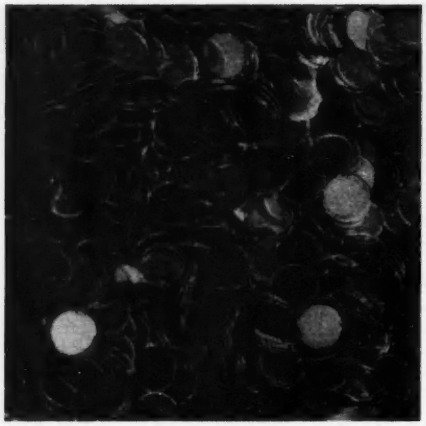


Fig. 6 (*a*)

Fig 6 (*b*)

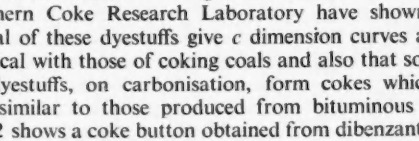
soluble part of the extract sometimes called the coal bitumen, on the other hand, on carbonisation gives a *c* dimension curve with a much more pronounced maximum at 550°C. There is therefore little doubt that the bitumen in the coal is responsible for systematic variations in the magnitude of the *c* dimension of the crystallites formed on carbonisation. It is also known, particularly from the work of Franz Fischer, that it is the bitumen, or more correctly a part of the bitumen, which is responsible for the coking properties of a coal; it therefore appears probable that these peculiar variations in the *c* dimension are in some way connected with coking phenomena.

X-ray diffraction photographs and chemical analysis indicate that the bitumen is made up of large, more or less flat, aromatic molecules. The sharp rise in the *c* dimension with increase in temperature up to 550°C. suggests that these flat molecules are free to move and pack together, after the manner of pennies in a box or flat fish in a basket, i.e. they behave quite differently from substances like cellulose, which form rigid structures at relatively low temperatures. This type of packing together is shown in Fig. 6. Fig. 6 (*a*) shows a large number of small celluloid discs in a highly disordered array after they have been poured into a box; if thermal vibration is simulated by tapping the box, they pack together in the manner shown in Fig. 6 (*b*). Freedom of movement of this kind also makes it possible for the flat disc-like molecules of bitumen to form continuous films, and there is little doubt that this power of forming films in the temperature range 400° to 550°C. is responsible for the agglutinating properties of coking coals. If on carbonisation only rigid crystallites are formed, or if film formation only occurs at low temperatures (which probably means that the carbonaceous substance contains a high proportion of oxygen which will be lost as carbon dioxide at higher temperatures), then a friable or powdery char will result.

It is not yet possible to state with certainty what causes the decrease in the *c* dimension between 550° and 900°C. (see Fig. 5); it may be due to a certain amount of crystallographic disorder caused by gas evolution during carbonisation, or the explanation may be much more fundamental.

Dyestuffs that Coke

The exact chemical structures of coal bitumen molecules are not known. It would therefore be much more satisfactory and lend support to the ideas outlined above, if we could imitate the X-ray crystallographic behaviour of coal on carbonising, with the behaviour of an organic compound of known structure. The results of chemical and X-ray investigation of coal bitumens provide considerable guidance in the choice of such a compound. We know, for example, that the compound must be stable and non-volatile at temperatures up to 500°C. which suggests that its molecules must be large and aromatic; it must contain elements other than carbon and hydrogen, otherwise it would be volatile; it must not, however, contain too much oxygen (or nitrogen which behaves like oxygen in this respect), otherwise it would char at a low temperature, forming only rigid carbon crystallites. Of all the organic compounds of known structures, certain vat dyestuffs appeared most likely to fulfil all these conditions. Recent investigations carried out in the Northern Coke Research Laboratory have shown that several of these dyestuffs give *c* dimension curves almost identical with those of coking coals and also that some of the dyestuffs, on carbonisation, form cokes which are very similar to those produced from bituminous coals. Fig. 2 shows a coke button obtained from dibenzanthrone (Caledon Deep Blue)



together with a button obtained from a Durham coking coal.

We can conclude from these discoveries that the bitumen part of a bituminous coal consists of large, disc-like, aromatic molecules, similar to but possibly considerably larger than the dibenzanthrone molecule, and capable of slipping one along another under the influence of thermal vibration. The remainder of the coal, which may be

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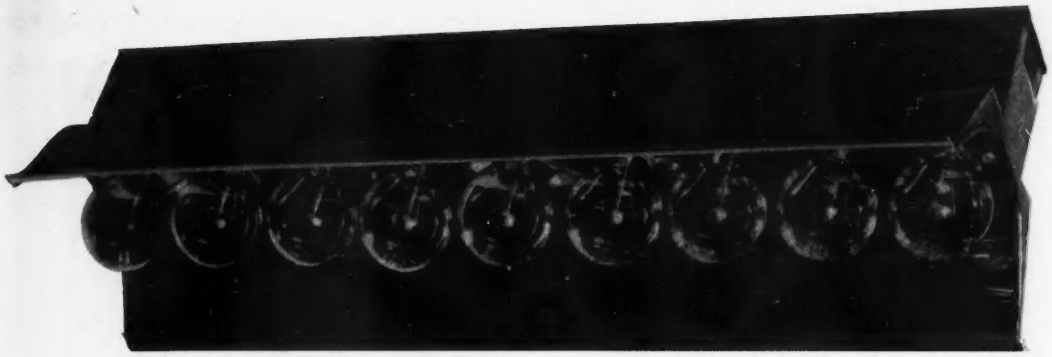

FIG. 1.—Steel Trough with rhodium-plated reflectors for Infra-Red Lamp Heating.

Infra-Red Lamp Heating in Industry

F. E. ROWLAND, M.I.E.E.

PERIODICALLY a new process is introduced into industry which not only offers outstanding advantages in production, but also makes an appeal to the imagination. Infra-Red Lamp Heating falls into this category on account of the outstanding benefits which accrue from its use and on account of the novel means employed for producing heat. The idea of using lamps for industrial radiant heating originated when difficulty was encountered in dealing with blemishes on motor-car bodies treated with synthetic resin paint. Local heating was required to harden the patch covering the blemish, and an ingenious solution was found which employed an electric lamp as a source of radiant heat.

Convection heating has been widely employed for paint drying and other industrial processes. The temperature of the object is raised by the transmission of heat from the surrounding air, which is at a higher temperature. This method is comparatively slow, and for paint drying stoving times of an hour or more are not uncommon. The great advantage of radiant heating is the very rapid rate of heat transfer from the source to the objects to be heated, which attain their final temperature in a few minutes and paints may be stoved in a fraction of the time previously required.

Lamps as a Source of Radiant Heat

Infra-Red Industrial Lamps whilst similar to tungsten filament lighting lamps in appearance differ in construction, and operate at a lower filament temperature. Most of the energy produced is in the infra-red part of the spectrum, whilst a small proportion is in the visible portion. Lamps form a particularly efficient source of radiant heat; the bulb not only serves as a container for the inert gas by which the filament is surrounded but also protects it from convection losses. The small size of the filament is also an important feature as it forms a source of energy which is easily controlled by reflectors of suitable design.

To obtain the maximum efficiency from the filament heat-source reflectors of suitable design are employed. Originally, individual round reflectors for each lamp were used, and to obtain the maximum reflecting efficiency they were plated with pure gold, which has a high efficiency for reflection of infra-red energy. An improvement on this technique is the use of trough reflectors which have a number of advantages compared with the individual round type. Closer lamp spacing is obtainable which enables much greater heating intensity to be obtained, whilst when assembled in the banks employed in production plants an unbroken reflecting surface is obtained. Gaps through which draughts may enter the plant or glare escape from it are also entirely eliminated. A further improvement which has been incorporated with the trough reflectors is the use of rhodium plating in place of gold. Compared with gold, rhodium has the great advantage that it is an exceedingly hard metal resistant to wear and abrasion when cleaning, whereas gold is particularly soft and consequently very prone to damage.

Temperature Attained

The temperature reached in an article subjected to radiant heating is influenced by its composition and the nature of its surface. Heating is produced by absorption of energy at or immediately beneath the surface irradiated. If the surface absorbs energy readily, as in the case of a black body, heat is generated rapidly, whereas if the surface does not absorb energy readily, heating up will be slow and the maximum temperature attained will be lower. A good example of this effect is that of an aluminium sheet, which if it is brightly polished is a good reflector of infra-red and heats up very slowly, and the maximum temperature it will attain is comparatively low, whereas if the same sheet is covered with a dull black paint which produces a surface which readily absorbs infra-red energy, the sheet will heat up rapidly, and reach a higher maximum temperature. In the case of a thick article providing it is made from a good heat-conductor such as

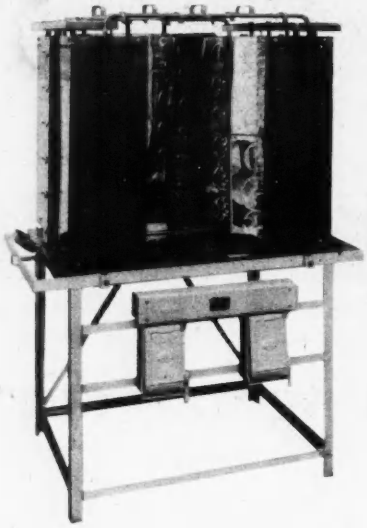

FIG. 2.—Small plant for Infra-Red Lamp Heating with adjustable banks and selective switching for lamps.

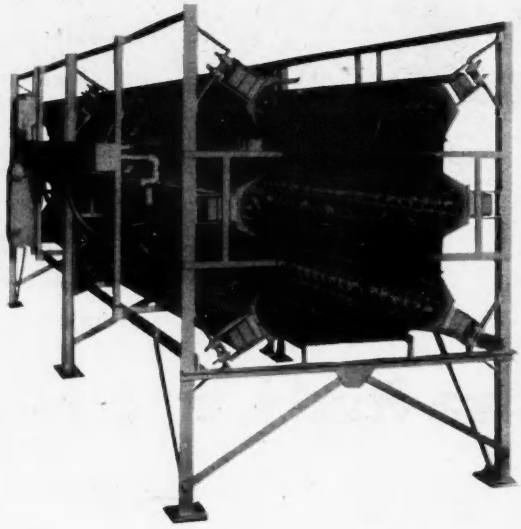

FIG. 3.—Infra-Red Lamp Heating Plant for stoving paint on ammunition boxes in 1½ minutes.

metal, the inside will heat up due to conduction from the surface; whilst if the material of which it consists is a bad conductor of heat such as asbestos, the conduction of heat will be very slow to the interior, which will not attain a temperature comparable with that of the surface. There is an erroneous idea abroad that with infra-red, heating of an article occurs from the inside outwards, but for all materials in general use this is not the case, as they are not transparent to this form of energy. With the lamp heating plant at present available maximum temperatures of the order of 600°F. are obtainable in metal articles, and these temperatures are attained in a few minutes. By comparison, with convection heating an article may not reach the maximum oven temperature at all, and will probably take half-an-hour or more to attain a value approaching it.

Plant Design

Because Infra-Red Lamp Heating Plants consist of components which have a familiar appearance and are similar to articles in common use, it is frequently assumed that the application is a simple one requiring little technical knowledge or experience. However, this is not the case, and to attain satisfactory results skilled knowledge and experience are required. Some prospective users who would not attempt to design their own convection plant are inclined to attempt to produce their own lamp heating plant, but without the requisite technical knowledge and experience this course is liable to result in failure. There is also an inclination to carry out tests on a much smaller scale than that which would be required in practice. Very misleading results may be obtained if this course is followed, as tests, to be an indication of what will result in practice, must be on a comparable basis. For instance, to ascertain the effect of heating a large metal article, it is valueless to heat a small area only of that article. Heat will be conducted away from the portion under test and it will not attain as high a temperature as would be reached if the whole object were heated uniformly.

Advantages in Industry

Whilst the principal advantage of Infra-Red Lamp Heating in industrial production is the great saving in time which may result from its use, the process has other advantages. It may be employed for dealing with stationary objects, and is particularly applicable to the continuous processing of similar articles on a conveyor. An installation may be laid out as a complete unit incorporating various processes in fabrication, assembly, painting, stoving, packing and despatch.

Paint Drying.—So far paint drying has been the principal application of Infra-Red Lamp Heating on account of the very rapid stoving times obtainable, reductions of the order of 90% being quite usual. With lamp heating 10 minutes is considered to be a long time, whereas with convection stoving an hour or more is common.

Paints may be divided, broadly, into two main types, those in which the drying process is reversible, and those in which it is irreversible. In the case of the first type drying is due to the evaporation of solvent and the resultant film may be redissolved by re-application of the original solvent. These materials dry relatively quickly without heating, and include spirit varnishes and cellulose derivatives. Drying of irreversible paints is due to chemical reactions which take place during the drying process, and the nature of the reactions depends upon the type of

FIG. 4 —Adjustable Infra-Red Lamp Heating Plant. Stoving Paint on Ammunition Boxes in 4 minutes.

paint employed. The reaction may be due to oxidation, a combination with oxygen in the air, or it may be by polymerisation, a chemical reaction in the medium itself.

Paints of the irreversible type may be made either primarily for air drying or primarily for stoving, but lamp heating may be used for accelerating the speed of drying of both types. The reduction in drying time varies with different types and depends on their characteristics. Those for which lamp heating can be used with the maximum advantage fall in the synthetic resin class, which are of the polymerising type.

The drying times for paints stoved in lamp heating plants vary widely according to the nature of the articles and the type of paint used. Some light sheet metal objects may be stoved in less than a minute whilst heavier objects may take 10 miuntes with a different type of paint. Five minutes is a reasonable average time for this type of work and compares with 30 minutes to 60 minutes in a convection oven, operating at air temperatures between 200°F. and 400°F.

Coil Drying.—Lamp heating may be used with advantage for drying insulating varnishes in coils used for electric appliances, such as small transformers and motors. The application is closely allied to paint drying, but as a maximum temperature of about 300°F. is set by the insulating material employed to cover the wire, the stoving times are longer than for straightforward paint drying. However, great benefit may be secured because in a convection oven times of the order of 24 hours are not uncommon, whereas with lamp heating this period may be reduced to something of the order of 2 to 3 hours, particularly when some of the modern synthetic varnishes are employed.

Drying Foundry Moulds.—When making sand moulds for metal castings they must be dried before the metal is poured, otherwise blow holes may be formed due to the escape of steam from the sand when the hot metal comes into contact with it. There are various methods employed for accelerating the drying of moulds including convection ovens, which are slow, and gas torches which depend on careful operation by the operator, otherwise uneven drying results. Particularly when it is only required to surface dry the skin of a mould, and providing its configuration is such that direct irradiation reaches all surfaces to be dried, substantial benefit may be obtained by using lamp heating. The method is rapid, and is entirely independent of the skill of the operator. It is particularly suitable for association with mechanised foundry methods, and in such cases lends itself to automatic control. Drying times of from 5 to 45 minutes are obtainable depending on the type of sand employed, its moisture content, and the depth of drying required.

Accelerating Setting of Adhesives.—Synthetic glues employed in the fabrication of wooden assemblies employed in the aircraft and furniture industries may be set rapidly

FIG. 5.—Forty-two foot Infra-Red Lamp Heating Plant for stoving paint inside and outside petrol cans in one operation. Time 7½ minutes.

by infra-red heating. When applying a veneer to a wooden structure it may take 5 to 6 hours for a glue to set at room temperature, and during this period much valuable space may be occupied. If by employing lamp heating the temperature of the glue line is raised to 160°F. the setting time may be reduced to 15 minutes, and a much larger output handled in the same space. Lamp heating may be used for this purpose for thicknesses up to about ½ in. to 1 in. as the heat will penetrate from the surface to the glue line. For greater thicknesses high frequency di-electric heating or some other method of electric heating may be more effective.

Textiles.—Heating is required for many processes in the textile industry for evaporating moisture, and for curing or partial curing of resin impregnated and synthetic rubber coated fabrics and similar materials. Although lamp heating is not necessarily the most suitable means for all such purposes, it may be employed in many instances with great advantage, and lends itself particularly to continuous processes in which the cloth passes between banks of lamps. The quality of the drying is very uniform, although for very heavy materials radiant heating may not be satisfactory, owing to the outside surface drying, and possibly scorching, before the inside is sufficiently dry. Resin impregnation is widely employed for proofing and making fabrics crease-resisting, and lamp heating may be used with advantage in curing such products.

Softening Plastics.—For many industrial processes applied to plastics, such as moulding and punching, the temperature of the material has to be raised so as to render it suitable for treatment. Bakelite, Perspex and cellulose acetate are typical materials the temperature of which may be raised by lamp heating. Softening times vary with the thickness of the material and the intensity of heating, and may range from 20 seconds to 15 minutes according to circumstances.

Miscellaneous Applications.—There are many other uses for heating and drying for which lamp heating may be employed advantageously. Printing inks may be dried, metal objects may be expanded in order that parts may be fitted together, moisture may be evaporated from various materials, and plastic moulding powders dried. Frequently when a new process such as lamp heating is introduced it is erroneously imagined that it is a panacea for all heating problems. However, this is not the case, and whilst lamp heating has a wide range of uses, there are many purposes for which it is not applicable, and for which some other form of electric heating may be employed with greater advantage.

Much valuable data and experience has been acquired in war-time which will be available for peace-time production, when new possibilities will be presented due to the wide variety of decorative finishes which will be used.

Counting Heads

TOM HARRISSON

In a recent number of the *Journal of Animal Ecology* there is a long and interesting paper on "The Breeding, Distribution, History and Population of the North Atlantic Gannet (*Sula bassana*)". The gannet is the largest of our sea-birds, snowy white, with long, black tipped wings, and a sharp, straight, yellow beak. It feeds on fish and other marine life, caught by flying from 50 to a couple of hundred feet above the water, eyes scanning the depths below. At any sign of food, it keels over, closes its wide wings, puts beak and long neck into a straight line, and plummets at 90 degrees into the water below, stupendous dive-bomber, disappearing in a shower of spray and splash. Before the war, James Fisher and H. G. Vevers organised a transantlantic system for studying this expert fisherman, which nests in snowy thousands on lonely rocks and islets both sides of the Atlantic. Since the war, with the collaboration of R.A.F. Coastal Command, valuable data has been added through air photography and counts of remoter gannetries.

Among other things, the authors have ascertained the birds complete world population, 165,600, second largest accurate census ever undertaken. A tremendous amount of work is involved in such counting. There are few other animals about the numbers of which we have any definite idea. Even the world's human population is sketchily known, and the war has put our information badly out of date. Whitaker's Almanac for 1941 estimates that there are some 2000×10^6 specimens of *Homo sapiens* to-day. In 1933, a census was taken of the American bison, once nearly extinct, now with 21,701 specimens, an increase of over 7000 in a decade. Counts of the Atlantic Gray Seal suggest that this fine, fat animal, found in the outer islands of Scotland, is now reduced to some 10,000 in number, whereas the Fur Seal still numbers over 2 million. The magnificent Wild Turkey of Florida numbered just over 12,000 in 1939. Then there are some populations known because practically extinct, the remaining individuals either in captivity or some sort of national park. Thus the curious American Ivory-billed Woodpecker is down to two dozen. There are some 300 remaining Trumpeter Swans, less than twenty wild. Similarly with the lovely Whooping Crane of America, now under 200, or the clumsy, ugly, unique Californian Condor, 45 still alive. Several famous tropical animals are now reduced to a mere handful. There are less than 200 of the Great Indian Rhinoceros, of the Javan Rhinoceros, the White-tailed Gnu, the European Bison and the Mountain Zebra. *All* the living specimens of Père David's Deer are in captivity at Wobern Park, Bedfordshire.

We do not yet know much about animal populations. Our knowledge is steadily increasing and a lot of attention is being paid to it by scientists. Complicated counting may seem rather a waste of time. It is not. We can learn a great deal from these studies. For instance, Dr. Charles Elton and others have shown, by regular counts in selected areas, that many animals have a regular *cycle*. They will be scarce; then they will gradually increase year by year until they reach the peak, after which they will decline again for a set period.

Organisations like the Hudson Bay Company, world's main source of furs, now adjust the annual kill of fur-bearing animals. This has proved invaluable in conserving supplies. On the other hand, information of this sort is valuable if you do want to reduce an animal. Try to eliminate the rabbit or vole in England during the peak years of their cycle; a hopeless task. On the other hand, don't be unduly depressed by mistaking this for a permanent increase. What you want to know is the trough year. That is the time to blitz them, reducing a large percentage of the whole population, thus seriously affecting their recovery to full strength. A lot of animals which "erupt" over the world, like the famous Arctic Lemming (which swarms in millions, and may even carry on out to sea, and die in millions), or the locust (which swamps whole countries),—these eruptions too are proving under numerical study to have a logical rhythm—capable of prediction, which greatly assists control. Much the same applies to germs, and other microscopic forms of life. The periodicity of influenza epidemics is already widely recognised.

When we can measure and understand these things we can deal with them. We need to know numbers of several bird pests, such as Magpie and Carrion Crow, in this country, and if they're increasing. Some years ago, I attempted the second complete national census of one bird—the Great Crested Grebe, increasing on English lakes, and exercising a considerable influence on the number of fish. Messrs. Fisher and Vevers also give me credit for one of the eight accurate complete counts of animal population. That was in 1931, when as one of a group of scientists on the lonely island of St. Kilda in the Atlantic, west of the Outer Hebrides, I put in much time scaling the colossal cliffs (highest in Great Britain) to pin-point the 68 nesting pairs of the tiny St. Kilda Wren, found nowhere else in the world.

Even a decade ago the main interest of naturalists was finding rarities, recording some peculiar bird at some peculiar place, at some peculiar time. That was the original focus of bird watching, butterfly collecting or rambling botany. This adds little to knowledge, and even less "useful" to man. Hobbies do not *have* to be useful, but if you can combine a touch of business, the pleasure is likely to be all the greater! Thus the ecological and systematic type of study has become more popular. If I may be personal again—I spent about five years travelling about the world, from Arctic to Equator, collecting rare animals for the British Museum and other people. I made some interesting discoveries, one or two of them remarkable, as these things go. But looking back on it, what a waste of effort and £ *s. d.*! After a while I got browned off, and decided to study human ecology. Since then, at far less cost, I have had more fun, and incidentally collected information useful to charitable organisations, social groups, Government bodies and such like. In the early

days, sociologists and anthropologists specialised in recording peculiar habits, remarkable rituals, odd abberations of man; like ornithologists, they too have seen a new light of interest through the study of *normality*.

To-day, methods applied to the world count of gannets are used in many ways, both for the present war and for post-war planning. We have always had population censuses. On the whole, however, it is fair to say that earlier counts were only of heads, seldom of hearts. The ecologist is not content merely with the numbers; he pieces them into a framework of behaviour, economy, psychology and so on. The Barlow Commission's report on the location of industry, published just before the war, is one of the best examples of this newer approach to human affairs. The Beveridge Report is a later specimen. UNRRA is faced with a world-wide dislocation of millions of human bodies, and even more immediately important human stomachs and human minds. The Minister of Health, Mr. Willink, has employed the most elaborate statistical methods to measure post-war housing need, as well as some sociological and psychological advice, to give the shell of home a heart of its own. He has been criticised for doing this job with insufficient imagination. On a more day-to-day basis, the Ministry of Food and the Board of Trade employ units to measure the human needs and weekly shifts of their market, the nation. The Ministry of Information has a branch which does nothing else but attempt to measure movements and tensions in opinion and morale. And so on.

It is clear, then, that the ecological approach, of comparatively recent origin in science (the *Journal of Animal Ecology* itself was only founded in 1932), though still young, has already proved fruitful, and is likely to prove increasingly so. Therefore, we must be careful. Percentages and decimal points easily impress the uninformed. Figures are specially dangerous when applied to the complicated human frame. Quantity alone is not enough. Quality is even more important, in the long run. It is not enough to know how many people want to live in flats or garden cities. It is already clear that under one in ten want to live in flats. We have got to get at something deeper. As a lot of people may *have* to live in flats after the war, how can these best meet dislikes and distrusts? How deep is the desire for a separate house, and what is the best way of catering for it in practical terms? What are the things inside a home which can most satisfy people, even though its situation may not be ideal? These, and many other questions, can only be answered by probing into people's minds, and will be overlooked in superficial studies, however accurate and detailed these may be.

An example of quantitative superficiality has been the talk in the House of Commons, the *Times* and elsewhere, about introducing a "No-Treating" order, to stop people standing each other drinks in pubs. The theory is that the more pubs and the more drinking facilities, the more drinking and drunkenness. That is a simple quantitative idea. *In fact*, if we take the number of pubs per ten thousand of population in any town, and compare drunkenness per ten thousand, we find the opposite. The towns with the most pubs per head usually have the lowest drunkenness per head, and *vice versa*. Where there are under ten pubs per thousand of the population, there are over eleven drunks per ten thousand. Where there are over 40 pubs per ten thousand, there are only just over four drunks.

Allowing for all the snags, and remembering that human ecology must include both quantity and quality, here is a good vehicle for the advancement of understanding and welfare. However gifted our politicians and representatives, no man to-day can take in the whole human scene with any degree of certainty, without the assistance of advisers and experts on a wide range of subjects. One of these subjects, hitherto neglected, is the feeling, habit, mood and opinion of the ordinary person. In the past, this has only been directly expressed in infrequent elections, or occasional uproars, which can only be decided on one or two major issues. It is in the minor issues of to-day and to-morrow that bodies interested in human ecology (such as the War-time Social Survey or Mass-Observation) can contribute. And the intelligent, critical interest of all thinking citizens is an essential part of this pattern too.

Information Centre for Visiting Scientists

THE Society for Visiting Scientists, with premises at 5 Old Burlington Street, W.1, has been founded on the initiative of the British Council in consultation with the Royal Society, to provide a meeting place and information centre where scientists can be given advice and information about scientific institutions in this country.

In many other countries admirable houses and organisations have been established for the use of visiting scientists and scholars. One of the best known of these is the Fondation Universitaire, Brussels; another remarkable centre is in Leningrad; it occupies one of the great palaces next to the Winter Palace beside the River Neva.

London hitherto has had no centre of the same kind, even on a modest scale, for it is not the function of the ordinary scientific societies to look after the more general needs of visiting scientists.

The Society's new premises at 5 Old Burlington Street, comprise a lounge, meeting rooms, and restaurant. The information centre will be at the disposal of visiting scientists, and any scientist arriving in Britain can, if he wishes, go at once to the house, use the facilities offered and find out how he may apply for membership.

The Committee controlling the affairs of the Society, includes among its members scientific representatives of the following countries: Belgium, Czechoslovakia, Greece, Holland, Norway, Poland, South Africa and the U.S.A., as well as distinguished British scientists.

Sugar - Beet Experiments in the U.S.S.R.

Professor VALENTINE DITIAKIN

SUGAR-BEET plantations occupy large areas in the northern latitudes, for, after many years' effort, man has greatly developed the existing cultivated varieties of cooking, fodder, and sugar-beet. Although 150 years ago 6% sugar was obtained with difficulty, beet has now been produced with 20% sugar content. Experiments have been practised in Russia continuously, and acquired great significance when the German invasion of Russia obliged us to push sugar-beet cultivation northwards.

As sugar-beet demands 5 frostless months, the Tula and Ryazan regions (Lat. 53° to 55°N.) have been considered the northern borderline of the sugar-beet areas. North and north-east of this line sugar-beet was never cultivated.

The employment of mineral fertilizer in the north produces a good effect, but better results are produced by combining mineral fertilizers with manure and lime.

Careful study revealed the importance of timely planting. Sowing monthly, though saving seed, requires arduous labour, so is recommended mainly for the northernmost districts and small gardens.

Of importance for the yield is constant digging of the soil between the rows, to keep it mellow during summer; otherwise the quality of the beet deteriorates, with a consequent decline in sugar content.

"Sub-feeding" crops during the vegetation period is important. Sub-feeding with nitrate fertilizers, which increases the yield from 1·2 to 2 tons per acre, is most effective.

Growth of beet and accumulation of sugar continues in the north until October 1st. It can be harvested in early October without any danger of loss due to frost, as spells of early cold do not harm it.

Spring grain must be planted in time, as a 10-day delay may affect the yield; while 20 days' delay may lead to a 1·6 to 1·8 ton decline in yield per acre.

The recent liberation of basic sugar-beet areas returns most sugar-beet production to the south, but experiments in planting conducted in the north will not lose their importance, as tasks connected with the north and north-east may demand the development of sugar-beet cultivation there.

Since 1941 attempts have been made in Russia to push sugar-beet cultivation to the north. The Union of Scientific Research Institute summed up the results of these experiments and undertook the study of the beet cultivation in the north and north-east. Experiments show that high sugar-beet yields may be obtained in the north. Yields of 20 to 28 tons per acre, with sugar content about 20%, have been obtained in Archangel, Vologda, Leningrad and Molotov and the Sverdlosk regions. Beyond the Arctic Circle, yields of 6 to 8 tons per acre have been obtained. During 1943 the Experimental Station at Naryanmar (at the mouth of the Pechora River) obtained over 6 tons per acre, while the yield obtained in the Snoloversk Islands (Lat. 65°N.) was about 18½ tons per acre with 17% sugar content.

Because of acid and poor soils in the north, organic fertilizers and lime treatment of the soil are important. Manure (8 to 16 tons per acre) increases the yield by 1·6 to 2·4 tons per acre, while lime treatment frequently doubles it.

HOW DOES COAL BECOME COKE? *Contd. from p.* 276

80% or more of the whole, is what Wheeler called the ulmin part of the coal; it probably has a much more complex structure than the bitumen part, but evidence has already been obtained that very close relationships exist between the ulmins and the bitumens, and it is not unlikely that further X-ray investigations will throw light upon the structure of ulmin and the related humic acids.

Bituminisation Coal

Mention was made above of the theories which have been put forward regarding the origin of the coking constituents in bituminous coals. There now appears to be little doubt that these views are incorrect. The work described above indicates that the development of coking properties during coalification depends upon the formation in the coal of a particular type of molecule. It must be large, aromatic, and contain a critical amount of oxygen; too much oxygen causes during carbonisation, the formation of rigid carbon crystallites at relatively low temperatures, and if the oxygen content becomes too small, rigid crystallites appear to be formed during coalification. Bone's investigations showed that the development of condensed aromatic structures was an essential part of coalification; increase in rank is also accompanied by a decrease in oxygen content. It therefore appears that the development of coking properties is a necessary concomitant of coalification, (provided the coalification progresses exceedingly slowly) and does not depend upon the presence in the original vegetable débris of a particular kind of carbonaceous material.

Although it is possible in the laboratory to increase the rank of "young" coal by gentle thermal treatment, it is not possible in this manner to develop or increase coking properties in the coal. Rapid maturing of coal, due to excessive rise in temperature, will result in the formation of rigid carbon crystallites, similar to those present in cellulose char, instead of in the formation of mobile bitumen molecules. In nature millions of years are necessary for the development of coking properties in coals, apparently for the same reason that makes it impossible to synthesize a vat dyestuff by the controlled pyrolysis of cellulose, although the final char has a highly aromatic structure.

Night Sky in October

M. DAVIDSON, D.Sc., F.R.A.S.

The Moon.—Full moon occurs on October 2d. 04h. 22m. U.T., and new moon on October 17d. 05h. 35m. The following conjunctions take place:

October

8d. 16h.	Saturn in conjunction with the moon	Saturn	0·3° N.
14d. 01h.	Jupiter ,,	Jupiter	3 S.
19d. 20h.	Venus ,,	Venus	5 S.

The Planets.—Mercury rises at 4h. 38m. at the beginning of the month and at the middle of the month about 10 minutes before sunset. The planet is in superior conjunction on October 20 and is not very well placed for observation during the remainder of the month. Venus sets at 18h. 22m., 18h., and 17h. 46m. at the beginning, middle and end of the month respectively. Mars is too close to the sun for favourable observation and at the middle of the month sets about quarter of an hour after the sun. Jupiter rises at 3h. 48m., 3h. 08m. and 2h. 22m. at the beginning, middle and end of the month respectively. On October 1 the planet is 587 million miles from the earth and at the end of the month the distance has decreased to 562 million miles. Saturn can be well seen before midnight, as it rises at 22h., 21h. 08m. and 20h. 05m. at the beginning, middle and end of the month respectively. On October 1 the planet is 839 million miles from the earth and at the end of the month the distance has decreased to 794 million miles.

Times of rising and setting of the sun and moon are given below, the latitude of Greenwich being assumed:

October	Sunrise	Sunset
1	6h. 00m.	17h. 38m.
15	6h. 23m.	17h. 08m.
31	6h. 51m.	16h. 35m.

October	Moonrise	Moonset
1	17h. 53m.	4h. 30m.
15	4h. 07m.	17h. 02m.
31	17h. 06m.	6h. 14m.

The Orionid meteors are active from October 18 to 20. It is possible that these meteors are due to the debris of Halley's Comet. This debris is spread out along the orbit of the comet and is encountered by the earth about the middle of the month.

Cacao Research in Trinidad

RESEARCH on cacao, initiated some years ago at the Imperial College of Tropical Agriculture in Trinidad, continues to engage the attention of various departments of the College.

The oldest of the cacao trees, propagated vegetatively from cuttings and planted in experimental blocks in the field, are now some six years old. Last year they yielded on the average about one pound of dry cacao per tree, which compares favourably with the yield of seedling trees of the same age. The best of the six cloves being tested gave more than two pounds of dry cacao per tree, equivalent to 600 pounds of dry cacao per acre.

Work on the physiology of cacao is mainly concerned with wilt of cacao fruits, and the changes in mineral and carbohydrate content of the fruit during development. Biochemical studies of the cacao bean include a differentiation of the tannin-like components. The aeration and water-supply as well as the decomposition of the organic matter of cacao soils are also being studied.

In both Trinidad and Grenada cacao fields are undergoing extensive rehabilitation or replanting with cacao cuttings or seedlings of high yielding propensity, and routine records of tree yields are being kept.

Insect pests of cacao are receiving special attention. Resistance of cacao to the cacao thrips has recently been demonstrated, and one thrips-resistant type is recommended for planting in areas liable to severe attack. The cacao beetle, a serious pest in both Trinidad and Grenada, is also being studied. The application of a lead arsenate and lime spray to young trees in rehabilitated or replanted fields has given effective control of this pest. Other insects attacking cacao are also being studied, and interesting information has resulted from a recent survey of the fauna of cacao soils.

Extensive field studies have been made of witches' broom disease of cacao. This is much the most serious disease affecting cacao in Trinidad and no successful method of control has so far been devised. The disease is also prevalent in South America, and recent introductions have been made from there, of material selected for resistance. It seems likely that the replanting of cacao types resistant to witches' broom disease will be the most satisfactory solution to this problem. A recent development is the discovery of apparently two distinct virus diseases of cacao in Trinidad, similar in many respects but much less virulent than the serious swollen shoot virus disease by cacao in West Africa.

JUNIOR SCIENCE

Heat and Temperature

Now and then we have been talking about the effects that heat has on substances. What does it really mean that a substance, let's say a bit of metal, is hot or cold? There is no difference to be seen between two similar spoons one of which has been lying in hot water while the other has been in the ice-box; their weight has not changed either. But you can *feel* a difference when you touch them; you say one is hot and the other is cold. That means that we have put heat into one of the spoons and taken heat out of the other one; the one that is hot has a higher *temperature* than the cold one. So, you see, the temperature of an object tells us how much heat has been *filled* into it. If we take two spoons out of the ice-box and fill twice as much heat into one than into the other it will become twice as hot. Heating an object is like filling water into a vessel. If you take two test tubes and fill twice as much water into one than into the other the water level will be twice as high in the one that has received twice the amount of water. In the same way the temperature of the spoon which has received twice the amount of heat has been raised twice as much as the temperature of the other spoon. You see, the temperature of the spoons tells us the "level" to which they have been heated.

By comparing the levels of the water in our test tubes we can say how much more water has been filled into one than into the other; we can *measure* the amount of water in this way. In the same way we can compare the amounts of heat that have been filled into our spoons by measuring their temperature with a thermometer. They had both the same temperature in the ice-box. If after heating the temperature in one spoon has been raised twice as much as in the other, we can say that it has received twice the amount of heat.

Measuring means comparing. If you measure a length, you simply compare it with a standard length that has been made up. Such standards are the inch and the centimetre. In measuring amounts of heat we simply compare them with a standard amount of heat which we call a calorie. A calorie is that amount of heat which raises the temperature of one gramme of water by one centigrade. If you have a sauce-pan with 312 grammes of water in it and you raise its temperature by leaving it for some time on the fire from 15°C. to 49°C., you can work out how much heat the water has received: $312 \times (49 - 15) = 312 \times 34 = 10608$. You have put in 10608 calories. Take a centigrade thermometer and find out how many calories pass into a sauce-pan from your gas ring every minute. I shall tell you more about heat and temperature some other time.

K.M.

The Bookshelf

The Origin of the Carolina Bays. By Douglas Johnson. No. 4 of the Columbia Geomorphic Studies; pp. xiii + 341, with 46 figs. Columbia University Press, 1942. (Oxford University Press, 1944; 30*s*.).

THE Coastal Plain of Carolina, particularly South Carolina, is pitted with innumerable depressions which, possibly from their common association with bay trees, are known to the inhabitants as "bays". They vary in size from a few hundred feet to three or four miles in length; most are irregular in outline, but many exhibit a singularly perfect oval form with their long axes approximately parallel, trending north-west—south-east. Before the advent of aerial photography, they did not attract much scientific attention; but aerial surveys made for forestry, military and other purposes have served to bring them prominently to the notice of geologists and geomorphologists. The present lavishly-produced volume provides a full description, a critical analysis of previous theories of their origin, and a detailed presentation of the late Professor Johnson's hypothesis of complex origin (the artesian-solution-lacustrine—aeolian hypothesis).

"The Carolina bays are without doubt one of the most remarkable geomorphic features on the surface of the earth. They share with submarine canyons the distinction of being among the most difficult of earth forms to explain." Among various theories put forward to account for them, none was more sensational than the meteoric theory elaborated by Melton and Schriever. According to this, the Carolina bays and the low, generally incomplete, rims of sand which frequently border them, have resulted from the impact of a shower of meteorites. This well-known theory is very carefully examined (in four complete chapters) before being discarded by Johnson as inadequate to account for all the features involved. Perhaps the most telling of the arguments against it is that even the largest known meteoric craters are only six-hundred feet in diameter or less (Meteor Crater in Arizona is four thousand feet, but this is doubtfully of meteoric origin); and such craters are deep in proportion to their area. None approaches in size the Carolina bays, some of which have a maximum diameter of three or four miles, and a depth of but a few feet. In fact, "even the largest meteorites known are insignificant when compared to the bodies required by the meteoric theory to form the Carolina Bays". No fragments of meteorites have been found associated with them, and magnetic tests (for buried meteoric bodies) are far from conclusive.

Johnson's "hypothesis of complex origin" envisages artesian springs coming up through openings in an impervious stratum and rising through ground water moving along superficial sands. Such currents appear competent to produce shallow lakes, for sand behaves very differently when water is moving upwards and downwards through it. The uprising current generates quicksand conditions, and slumping occurs where it meets the surface, whilst the downward current (as the water seeps away) produces compact and stable conditions. Moreover, the regional dip of the Coastal Plain strata is south-easterly, and if an opening in the impervious (probably calcareous) layer is enlarged against the dip (e.g., by solution) the surface crater will enlarge in an up-current direction, converting a circular lake to one of oval or elliptical outline. The regional dip in North Carolina differs slightly from that in South Carolina, and it is observed that the elongation of the oval bays is slightly and correspondingly different in the two States.

As a result of wave action on the shores of the lakes, many developed (by normal shore-erosion processes) a remarkably perfect oval form. Normal deepening of the river valleys in the newly uplifted Coastal Plain lowered the water-table, converting what were originally lakes into dry or marshy bays, and ridges if wind-blown sand accumulated around their margins, particularly on the leeward side.

This brief abstract, noting but a few of the salient arguments, is almost an affront to the logic and clarity with which Johnson expounds his theory, marshalling a wealth of illustrative detail. O.M.B.B.

The Application of Radiant Heat to Metal Finishing. By J. H. Nelson and H. Silman. (Chapman & Hall, 1944; pp. viii + 180 + 36 pls.; 8*s*. 6*d*.).

"HEAT is transferred by convection, conduction and radiation" say the textbooks. The pupil notes it down and hurries on to the rarer and more exciting radiations such as X-rays, γ-rays and cosmic rays. But anyone who has had any experience with infra-red radiation other than in spectroscopy soon realises that the homely infra-red rays offer a field of study of very great interest and possibilities which are at first by no means obvious. They should not be despised merely because they are so common and modern industrial practice in a great variety of fields is making increasing use of the infra-red region.

This particular book will have two audiences. One consists of the important band of technical workers in factories who are concerned with problems of drying and stoving paints and varnishes. The second, larger perhaps and even more important, consists of all scientific workers who use infra-red radiation. These, whether they be concerned with the chemical, engineering or medical applications of infra-red will derive profit from the reading of the excellently written general sections of this book.

These sections alone, the photographs, tables and monograms, would make the book worth buying. It fills a very real need both generally and more specifically by making available the latest radiant heat practice to the engineering profession. D.S.E.

Textbook of Sound. By Edmund Catchpool and John Satterly, sixth edition, revised by C. T. Archer. (University Tutorial Press, Ltd.; pp. 360 + 160 diags.; 8*s*.).

THIS is a textbook of the old school in which hands whose wrists are adorned with starched cuffs carry out the manipulations of the diagrams. It is regrettable that one gets the impression that most of the rest of the book is of the same vintage. It escapes by a hairsbreadth from being a textbook of applied mathematics instead of physics, because it includes accounts of a large number of experiments which should dispel the familiar illusion that once the student can do all the calculations he knows all about physics. But what experiments! Tyndall, Edison's phonograph, Helmholtz and Wheatstone are the authorities cited. The history of science is important but surely we ought not to imitate the practice of some history books and stop dead in the middle ages.

Perhaps it is due to the war that a really adequate rewriting has not been undertaken, but whatever the reason it can hardly be claimed that this is a suitable modern textbook. D.S.E.

A Shorter History of Science. By Sir William Cecil Dampier, D.Sc., F.R.S., (C.U.P., 1944; pp. viii + 189; 7*s*. 6*d*.).

IN his preface the author states that he has had two main objects in view in preparing this shorter version of his now well-known *History of Science and its Relations with Philosophy and Religion*. Of these the stronger, no doubt, has been the desire to meet the demand of many who have found the philosophical part of the larger work hard to follow, and have asked for a straight-forward story of the growth of science. In complying with this request, however, Sir William has exercised a wise discretion. He has simplified as well as shortened his narrative, but not by eliminating entirely references to the philosophy and religion of the periods with which he deals.

As everyone who has followed the history of science from its beginnings must be well aware, to understand even in part the present position of science in relation to thought and to society it is necessary to know something of the manner in which science, philosophy and religion have acted and reacted upon one another in the past. Remote in interest as Greek philosophy may seem at first sight, it still affects scientific thought to-day; nor has modern society entirely cast off the trammels of the early Christian Church in its attitude towards the science and philosophy of its day. Those who read Sir William Dampier's lucid outline of the development of scientific thought—not merely, be it noted, of scientific discovery—with the close attention it deserves will not fail to appreciate why the scientific spirit of discovery made manifest by Copernicus, by Galileo, by Newton and many others, is among the strongest of the living forces which animate the liberal and progressive element in the world of to-day. E.N.F.

Far and Near

Industrial Research in India

DURING the last four years of its existence, the Council of Scientific and Industrial Research in India has been engaged on a number of industrial processes of the highest value, not only for the immediate war period but also to be helpful for industrial development in the post-war period.

A report in the *Journal of the India Society of Engineers* for March says that some of the products evolved are of immediate war importance, and the detailed processes connected with their manufacture have been placed at the disposal of the Supply Development Committee.

An important line of investigation is the manufacture of useful products from raw materials available in India. Some of the products evolved by the Council have actually been from reclaimed or waste materials.

A number of processes have been already leased out to industrialists. Mention may be made in this connection of air foam solution, barium chloride, potassium chlorate, glass substitute, urea, formaldehyde, solid fuel, cork substitutes, plastic collapsible tubes, identity discs, laminated paper and fibre boards, which are already in production on an industrial scale. Dettol type of disinfectants, jute boards, small carbon electrodes, stearic and oleic acids, manganese dioxide from manganese ore for dry cell manufacture, pyrothrum emulsifer, water-proof paints for textiles, indigenous moulding powder, jute mill bobbins, are in the stage of industrial development.

Information is available from the Office of the Director of Scientific and Industrial Research (India) that investigations on the manufacture of some other useful products from indigenous raw materials have been successfully concluded. They are about twenty in number and the Industrial Research Utilisation Committee is reported to be already conducting negotions for the lease of some of these processes for industrial exploitation.

Voices Recorded on Steel Wire

A continuous speech of 66 minutes can be recorded on 11,500 feet of hair-like steel wire, on a spool of about 4 inches in diameter, by means of a new type of wire sound recorder now being made by the General Electric Company, according to an article in the Feb. 1944 issue of the *Journal of the Franklin Institute*.

Operating under a licence from the Armour Research Foundation, engineers in the Company's laboratory are now engaged in redesigning this recording apparatus so that it can be mass-produced, to meet the demands of the Army and Navy. The recorder itself is contained in a small box weighing about 9 lb. It has many war-time uses, the most important probably being its use in observation planes. Instead of the pad and pencil at present used by pilots to make notes when on reconnaissance flights, a small microphone will be provided, into which the airmen can dictate their observations, just as a busy office worker uses a dictaphone.

Unlike the wax cylinder, which is breakable, the wire does not apparently wear out. In fact, 100,000 reproductions have failed to alter the quality of a wire in any respect. When the recordings are no longer needed, the speeches can be "wiped off" magnetically; the wire is still as good as new, and can be used for fresh recordings.

Recording by means of magnetic steel wire is not a new idea. As long ago as 1898, Valdamar Poulson, a Danish scientist, introduced the method and used it to record high-speed arc radio signals. However, suitable amplifiers were not available at that time, and the quality of the recording was poor. Since the method has been developed by Marvin Camras, assistant physicist of the Armour Institute, many changes have been made, and the quality improved so much as to compare favourably with ordinary phonograph records.

A recent report stated that the sound recorder is now being used in war zones, and that "the conversation of a Flying Fortress crew, attacking Nazi airfields in France, was recorded on a small spool of wire". This recording was brought back to England and according to Major H. L. Nussbaum, "all the conversation of the Fortress crew, as well as the sounds of battle, was brought back as an oral record of the 66 minute flight".

Schools Broadcasting

THE B.B.C. Schools Broadcasting Service commences its Autumn term on September 25th. Apart from the actual programme to the schools, the B.B.C. offers considerable ancilliary aids to the teacher who wishes to co-operate with the Council for School Broadcasting in effecting the best possible class use of the service.

Upon registering the School with the B.B.C. Council for School Broadcasting at 55, Portland Place, W.1, a copy of the programme schedule for the autumn, spring and summer terms will be available. Leaflets for teachers who wish for further information upon various subjects broadcast may also be obtained. Schools having difficulty about the supply or repairs of a receiving set should communicate with the Council.

Among the regular radio lessons of particular interest to DISCOVERY readers to be heard during the new educational year are those on General Science, Nature Study, Gardening, How things Began, Geography and Travel Talks; but a much wider curriculum has been wisely chosen by the Council.

Electricians' Offer to Cambridge

CAMBRIDGE University will probably accept the offer of the Institution of Electrical Engineers to endow for a limited period (probably five years) a professorship of electrical engineering at the University. Although this will be a departure from precedent of perpetual endowment, the University authorities may be willing to make the necessary provision for the continuance of the professorship if external aid is not forthcoming. It is hoped, says the *Electrical Review* that the electrical profession and industry will see that no financial difficulties interfere with the operation of this very excellent plan.

Mosquitoes and Static Water Tanks

FROM time to time concern has been expressed at the possibility of mosquitoes breeding in static water tanks used for fire-fighting. A reassuring account of the real position is given by P. G. Shute, in the *Journal of the Royal Sanitary Society* as long ago as July 1943. He said then that the only mosquito larvæ so far found in these tanks were those of *Culex pipiens*, a species which does not feed on man, its chief source of blood meals being obtained from birds. This is a common species, and indeed, it is rare to find a rain water butt or other artificial collection of water which is not infested with larvæ of *Culex pipiens*. In the autumn the females invade dwelling houses (the males die off about that time) where they may become a source of irritation, so that measures against this harmless species are therefore justified. Possibly this state of affairs, with *Culex pipiens* as the only species breeding in large numbers, may not continue, and there has been some surprise that another mosquito, *Theobaldia annulata*, which has a vicious bite, has not so far been found occurring in static water tanks.

In London the responsibility of examining the tanks for mosquito larvæ has been assumed by the National Fire Service. If larvæ are found the water is treated immediately, and where various types of insect larvæ are found and require identification, samples are sent for classification either to the Ministry of Health or to the Natural History Museum.

Static water tanks are only treated when larvæ are found, oil being used for control in iron and brickwork tanks, one gallon of oil being sufficient to cover 2750 square feet of water. Where oil cannot be used, as for instance in tanks that are lined with bitumen, an insecticidal compound must be used; so far, however, larvæ have not been found in bituminized tanks.

To prevent mosquitoes breeding in water butts and cisterns the writer recommends that these should be covered with a close-fitting lid to prevent mosquitoes depositing their eggs on the water. Such lids are not practicable for large static water tanks. Mosquito larvæ seem to thrive in tanks which are less than half full of water; for instance out of one battery of eight tanks, three contained only a few inches of water and five were full—no larvæ were found in the latter, but the three nearly empty ones were swarming; therefore it is important that the tanks should be filled to the brim.

The growth of aquatic vegetation—particularly of algæ—creates the conditions under which the larvæ thrive, and therefore plant growth should be

destroyed whenever it is found; copper sulphate at the rate of 3½ lb. per million gallons of water is effective.

In London's underground railways over 90% of the collections of water have, at one time or another, contained mosquito larvæ; therefore, all such water is regularly treated whether larvæ are present or not seeing that so many patches of water are infested.

Synthetic Analysis of Plastics

WITH so many different chemical types of plastics, systematic analysis is a very complicated matter. Up to the present comparatively few investigators have organised a comprehensive scheme. The information available is very scattered over a wide field of activity.

In the August issue of *British Plastics*, Dr. Harry Barron makes an effort to fill this gap in the literature of plastics by contributing the first article of a series entitled "Analytical Aspects of Plastics".

New Investigations in Mitosis

POINTS of departure for new investigations of the movements of chromosomes in cell division are suggested by Franz Schrader, professor of zoology in Columbia University, in *Mitosis*, a scientific survey published by the Columbia University Press.

Summarising studies on the movement of chromosomes made over a 25-year period, Professor Schrader indicates the meagreness of known facts concerning mitosis, a problem which confronts all biologists, as well as specialists concerned with normal growth and with abnormal growths such as cancer.

"A survey of past attempts to solve the puzzle that is mitosis may well seem disheartening", Professor Schrader declares. "Not one of the many hypotheses that have been broached has in it the definite promise of a final solution. But we have come to realise that mitosis is comprised of a great complex of different mechanisms. To win this realisation is perhaps a small reward for our efforts, but one must remember that such an attitude is not of long standing.

"The investigations of the past have usually gone out from the assumption that the whole mitotic mechanism when laid bare will prove to be rather simple. In no other way can one explain the fact that nearly all the hypotheses have been built around the idea that a certain, single type of force underlies all mitotic activity, and that variations and adjustments in this force and the cell elements will explain the whole cycle of phenomena with which we are confronted. Thus we have contraction, expansion, hydration, diffusion and electrical forces, each serving as the core of various hypothese. It is evident that the solution of the problem cannot be achieved in that way.

"Scientists in other fields are wont to express astonishment that the experimental method has been used with so little success in analysing mitosis. To one who has tried it, the explanation is obvious. It lies in the fact that it is almost impossible to affect a given structure or process of the mitotic mechanism, be it by operation or physiochemical means, without simultaneously affecting several others. Usually it is difficult to determine the nature and the precise influence of the disturbing factors thus introduced, and the intrusion of subsidiary effects may not actually become recognisable until a later period, if at all.

"It is quite possible and even probable that the majority of mitotic hypotheses have a portion of truth in them. Thus it is not venturesome to predict that electrical forces are involved, for such forces are certainly active in the cell and it is very likely that they affect the mechanics of mitosis. Similarly hydration, dehydration, and diffusion are normal concomitants of the life of the cell, while alterations in viscosity are known to occur regularly in the cell cycle. These all probably play important roles in mitosis and in the main the difficulty lies in determining just what those roles are.

"Newer aspects that have arisen from an increase in our knowledge of the physical chemistry of the cell may become extremely important, as for example the behaviour of tactoids. Usually, however, it is not obvious how such information fits into the knowledge that we already possess. Such recent advances therefore gain a special interest when they throw new light on older hypotheses. This bids fair to be the case in the discoveries on the behaviour of polypeptide chains which may well restore to high standing the oldest hypotheses of all, the contraction and expansion of spindle fibers.

"The attitude of the past that the answer will some day be revealed to us by a stroke of genius or by luck is almost certainly illusory. The solution will be approached much more surely if we make up our minds that we are confronted by some painstaking work that has to be guided by intelligent planning and a thorough knowledge of the results so far obtained".

Personal Notes

DR. STEPHEN JOHN WATSON, director-in-charge of Jealotts Hill Agricultural Research Station of I.C.I. Ltd., has been selected to succeed Professor Ernest Shearer as professor of agriculture in the University of Edinburgh. He also becomes principal of the Edinburgh and East of Scotland College of Agriculture. He is aged 46.

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THE offices of registrar and secretary to the Royal Institute of Chemistry, at present both held by MR. R. B. PILCHER, are to be separate as from the beginning of next year, when MR. R. LESLIE COLLETT will become registrar (after twenty years service as the Institute's assistant secretary) and DR. H. J. T. ELLINGHAM, now of the Imperial College of Science and Technology, will take up his post as secretary.

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DR. NORMAN P. ALLEN has succeeded DR. C. SYKES as superintendent of the metallurgy department of the National Physical Laboratory.

MR. A. A. HALL has been appointed Zaharoff professor of aviation at the Imperial College of Science and Technology in succession to PROFESSOR LEONARD BAIRSTOW. Since 1938 Mr. Hall has been engaged on aeronautical research as a member of the staff of the Royal Aircraft Establishment.

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MR. C. T. GIMINGHAM, O.B.E., B.SC., F.R.I.C., has been promoted to the post of Director of the Plant Pathology Laboratory of the Ministry of Agriculture and Fisheries at Harpenden to succeed MR. J. C. F. FRYER, O.B.E., M.A., who has been appointed Secretary to the Agricultural Research Council.

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SIR HENRY LYONS, F.R.S., whose death took place last month, in his 80th year, will be best remembered from his work at the Science Museum, South Kensington, London. While acting as Director and Secretary from 1920 to 1933, by his administrative and organising ability he brought the Museum to the highest pitch of efficiency in meeting the needs of both scientists and the general public.

Sir Henry first won recognition in the field of science while still in the Army—he was gazetted to the Royal Engineers in 1884, returning in 1901—while he was seconded from service with the Geological Survey of Egypt from 1896-1900.

Of the Nile and the cadastral survey of Egypt, he made an invaluable record of the condition of the island and its temples before the inundation on the opening of the Assouan Dam. During the War of 1914, Sir Henry Lyons served as Director of the Army Meteorological Service and at its close, became director of the Meteorological Office. He acted as Treasurer of the Royal Society, 1929-39, and in 1926 received a Knighthood.

Sir Henry was also a member of the publication committee of DISCOVERY in an early stage of its existence.

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SIR ARTHUR SMITH WOODWARD, F.R.S., whose death at the age of eighty years took place on 2 September, was formerly Keeper of the Department of Geology, British Museum (Natural History). While still an undergraduate of the University of Manchester, he was appointed to the staff of the Museum in 1882, not long after it had been moved to Cromwell Road, South Kensington. The palaeontological collections were then in process of being rearranged and he entered upon this work with enthusiasm. From 1892 when he became assistant-keeper of geology his unceasing efforts to secure completeness in the Museums collections in vertebrate palaeontology, and his unimpeachable accuracy raised these collections to a foremost position in the estimation of scientific workers throughout the world. The first fruits of his work on the collections was a monumental and authoritative "Catalogue of Fossil Fishes in the British Museum" which appeared in four volumes, (1889 to 1901). He was the author of numerous papers and memoirs in geology and palaeontology, and travelled extensively in the interest of his

studies in many parts of the world, but more especially in South America where he made a special study of extinct forms peculiar to that region. One of his most notable achievements, however, was in the field of human palaeontology. This was the recognition and appreciation of the significance of the fragments of a fossil skull which in 1911 had been found by Mr. Charles Dawson at Piltdown in Sussex. His reconstruction of the fragments as the skull of Piltdown Man still holds the field as one of the most convincing of the several attempts which have been made to demonstrate the characteristics of one of the earliest links in the chain of human evolution. Sir Arthur retired from the British Museum in 1924, receiving the honour of Knighthood. The value of his work was recognised by the award of medals and other honours by universities, acadamies and learned societies in all parts of the world.

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DR. ETHEL N. M. THOMAS, Fellow of University College, London, died on 28th August. She was formerly Reader in Botany in the University of London, and had been head of the Department of Botany, University College, Leicester, and in charge of the Botanical Department, University of South Wales and Monmouthshire and the National Museum. She was an Honorary Director of the Botanical Research Trust Laboratory, and had herself made a number of valuable contributions to the literature of botanical research. During the present war she served as temporary Inspector of the Board of Agriculture.

Scientific Policy for Agriculture

THAT the Government's future policy for agriculture in this country should be based upon scientific principles and co-ordinated with the country's nutritional requirements is recommended by the Parliamentary and Scientific Committee's report *A Scientific Policy for British Agriculture* (9*d*.).

The Committee endorses the recommendation of the United Nations' Conference at Hot Springs, namely "that production of nutritionally desirable foods, which can be obtained from elsewhere only with difficulty or not at all, is a special obligation of the agriculture of every country," and that farming systems should be designed to maintain soil fertility, adequate return for labour, protection from diseases for crops and livestock and steady employment throughout the year.

Every step should be taken, says the Committee, to disseminate useful scientific knowledge as rapidly and effectively as possible to farmers through publicity, of every kind, including demonstrations, meetings, classes, films, displays, and regional advisory services.

Research in Puerto Rico

STUDIES of experimental leprosy in a search for medicines that might arrest or control the disease have been undertaken at the School of Tropical Medicine, operated under the auspices of Columbia University, at San Juan, Puerto Rico. Other war-time researches under way at the School relate to tropical diseases, botanical drugs, native oils, and diet in Puerto Rico, the annual report of Dr. Morales Otero, the director, discloses.

Mice are being used in the leprosy work. Since leprosy can be given to them in a short time, it appears possible to tell within a month or two whether any drug, glandular secretion, or other medicine will be effective, the report says.

Projects also are being carried out on skin and fungus diseases, on sprue, on a rapid method for classifying strains of dysentery bacilli, and on typhus and Weil's disease, an acute infectious jaundice.

The content of Vitamin E and C in foodstuffs in Puerto Rico, and the effects of various diets on health also are being investigated. In still another field, chemical studies are being made of native oils and "maya" juice, with progress that may make "maya" juice available for industrial uses.

X-Rays and Lead Screens

Two interesting publications have just been issued by Ilford Limited. These are a leaflet, "*Ilford Lead Screens for Industrial Radiography*", and a booklet, "*X-ray Darkroom Practice*".

The leaflet explains the necessity for using lead screens in industrial radiography, in order to prevent the harmful effects of scattered radiation and to improve the process by placing lead foil in contact with the film. However, reliable lead screens could not be made commercially available until the most suitable lead alloy and the best thickness of foil had been discovered. Ilford Limited claim to have solved this problem, and are now producing lead screens, from the use of which a better standard of radiography and improvements in time and clarity of exposure result.

The booklet, *X-ray Darkroom Practice*, deals with the responsibilities of the darkroom worker in the care of X-ray films, and stresses the need for avoiding any faults in the darkroom procedure which may damage or ruin the finished results. It describes simply and clearly the process of darkroom practice, giving a detailed account of all the processes, together with many hints on correct technique and care of equipment. It emphasises the need for perfect knowledge both of the process and of the factors governing control of the process, and explains how any faults in the X-ray film may be diagnosed and remedied. This is a simple but useful booklet, and is invaluable to the darkroom worker.

Trinidad Plant Quarantine Station

THE Plant Quarantine Station of the British West Indies, situated at the Imperial College of Tropical Agriculture in Trinidad, serves the British territories in the Caribbean region.

Many new varieties of sugar-cane, developed at the Barbados Central Cane Breeding Station, are grown in quarantine in Trinidad and eventually released for general distribution in the area. Among the most important plants recently handled were numerous small budded cacao trees, selected in Brazil for resistance to witches' broom disease. These were grown in quarantine for many months. Cuttings were released this year for propagation on a large scale and eventual distribution.

Although sugar-cane and cacao are dealt with most frequently, bananas, manila hemp, pineapples, citrus, cotton and other tropical plants of economic importance are from time to time received at the station.

Science Masters' Association

THE Report of Committee for 1943 shows that the Association has progressed very satisfactorily. Figures show that the number of members is now 2621, compared with 364 in 1919, while 965 schools are now represented. The financial position is also very good. *School Science Review* has been improved, and more attention is being given to the publication of official reports, and comments on these by members. Correspondence from members is also encouraged in order to compensate for the impossibility of holding annual meetings. The Higher School Certificate Sub-Committee has spent much time this year in revising the examination syllabus. One of its principal aims has been to widen the field of general education of science candidates for University scholarships.

Other activities during 1943 have included the formation of a Chemistry Education Advisory Board, which has produced a report on "*The Education and Training of Chemists*". A Scientific Film Association has also been established. Unfortunately, owing to war-time conditions, there have been no activities among the Association's eight branches, but it is hoped that some of the branches will this year have some opportunity of holding occasional meetings.

The President of the Association for 1944 is Dr. William Cullen, M.I.Chem.E., F.I.C., Chairman of the Council of the Society of Chemical Industry.

A Film of Tongue Movements

To understand the mechanism of speech, a close study of the movement of the tongue is essential. All language students realise how difficult it is under normal conditions first to investigate these movements and then to pass on that information. Recently, though the co-operation of a patient whose tongue was exposed as a result of an operation for the removal of part of his right cheek, a technicolour and sound film was made whilst he articulated some sounds of the English language. In the July issue of *Endeavour*, the making of this film in the Middlesex Hospital is described by Dr. Yule Bogue and Mr. Dennis Fry the phonetician.

Among a wide range of articles in the same number, Professor Blunt contributes an interesting essay on "Climate, Weather and Man", which apart from its scientific interest makes the suggestion that the early civilisations were established in parts of the world where the temperature was between 75° F. and 40° F. It was not until artificial means of heating buildings was discovered in Europe that higher forms of civilisation were able to establish themselves there and in this country.

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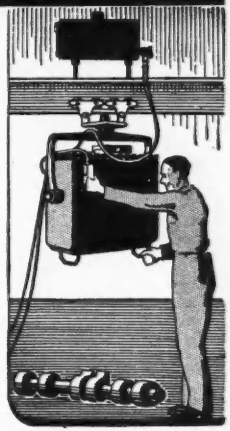
ILFORD PRODUCTS
FOR INDUSTRIAL RADIOGRAPHY



THE progress of Industrial Radiography has made apparent the need for a range of sensitized materials varying in their particular characteristics according to work to be done. Such a range of materials providing for every known requirement of the Industrial radiographer has now been made available by Ilford Limited and comprises three distinct types of films, intensifying screens and X-ray papers. These materials are described briefly below.

ILFORD X-RAY FILMS

Industrial X-ray Film A—a general purpose film for use with or without screens.

Industrial X-ray Film B—a high contrast, non-screen film for direct exposures (or with metal screens) for maximum flaw-discrimination.

Industrial X-ray Film C—a slow fine grain non-screen film for high resolution in crystallography or in the radiography of light alloys.

ILFORD X-RAY PAPERS

Ilford (Standard) X-ray Paper—for use with or without an intensifying screen.

Kryptoscreen X-ray Paper—for use with or without Brytex Intensifying Leaves—an exceptionally fast high resolution paper.

ILFORD INTENSIFYING SCREENS

Tungstate Screens (for cassette mounting)—for use with Industrial X-ray Film A.

(a) Normal pairs—consisting of thin front and thick back screen, for use at relatively low kilovoltages.

(b) Industrial pairs—consisting of two thick screens, for use at kilovoltages greater than 100-120 kV or with gamma rays.

Flexible Tungstate Screens (Normal or Industrial pairs)—coated on thin card base or on celluloid.

High Definition Tungstate Screens (for cassette mounting)—giving greatly improved definition, but having only half the speed of the normal Tungstate Screens.

Brytex Intensifying Leaves—specifically intended for use with Kryptoscreen Papers; usable also with Industrial X-ray Film A with moderate intensification factor.

The following Ilford booklets contain full information of all Ilford Industrial X-ray materials and will prove useful to Industrial Radiographers.

"Ilford Products for Industrial Applications of X-rays and Gamma Rays."

"Photography as an Aid to Scientific Work."

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THE ACID TEST

NO mere colloquialism. Sulphuric acid is so widely used in Industry that it is commonly taken as an index to the state of trade. The acid is used as it is produced and therefore the chart of its consumption reflects the fluctuations of business quickly and closely. Acids, with their opposites, the alkalis, are both in volume and range of uses the most important direct contribution of the chemical industry to Production. There is scarcely a commodity, scarcely even a single article which can be made without either acids or alkalis entering at one or more stages of its manufacture. Sulphuric acid, otherwise known as oil of vitriol, is used in almost every conceivable industry. It is noteworthy that the modern method of producing the acid from iron pyrites, air and water was suggested in 1831 by Peregrine Phillips, a Bristol vinegar brewer. The other essential "heavy acids" are nitric and hydrochloric. Tens of thousands of tons of nitric acid, once known as "aqua fortis" or "strong water," are produced by the British chemical industry every year, and more in war even than in peace, for it forms the basis of nearly all explosives, as well as of the inorganic fertilizers which are today required in increasing quantities to grow more food from British soil. Hydrochloric acid, or spirit of salt, is a combination of hydrogen with chlorine and finds wide uses in the metal pickling, tanning and textile trades. The heavy acids are in one sense the manufactured products of the chemical industry. In the much wider sense they are essential raw materials without constant and adequate supplies of which the wheels of production would stop turning. It is reassuring that the British chemical industry is the largest manufacturer of heavy acids in the world.

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